



## State of Louisiana

### Coastal Protection and Restoration Authority of Louisiana (CPRA)

## 2015 Operations, Maintenance, and Monitoring Report

for

## Black Bayou Hydrologic Restoration

State Project Number CS-27  
Priority Project List 6

June 2015  
Calcasieu and Cameron Parishes

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## Preface

The Black Bayou Hydrologic Restoration (CS-27) project was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 6th Priority Project List with the National Marine Fisheries Service (NMFS) as the federal sponsor and the Coastal Protection and Restoration Authority (CPRA). The 2015 OM&M Report format combines the Operations and Maintenance annual project inspection information with the Monitoring data and analyses for the project. This report includes monitoring data collected through December 2014, and annual Maintenance Inspections through June 2015.

The 2015 report is the 5<sup>th</sup> report in a series of OM&M reports. For additional information on lessons learned, recommendations, and project effectiveness please refer to the previous OM&M reports from 2004, 2005, 2008, and 2012 on the CPRA web site (<http://lacoast.gov/new/Projects/Info.aspx?num=CS-27>).

## I. Introduction

The Black Bayou Hydrologic Restoration Project (CS-27) is located in northwest Cameron and southwest Calcasieu Parishes. The project is bordered to the north by the Gulf Intracoastal Waterway (GIWW), to the south by Black Bayou, to the east by Gum Cove Ridge, and to the west by the Sabine River (Figure 1). Total project area is approximately 27,948 acres (11,310 ha) and was originally comprised of approximately 16,247 acres (6,574 ha) of intermediate and brackish marsh and 11,700 acres (4,735 ha) of open water. The marshes in the project area are dominated in large part by monocultures of *Spartina patens* (marshhay cordgrass), with a cohort of subordinate species consisting of *Phragmites australis* (Roseau cane), *Panicum dichotomiflorum* (fall panicum), *Typha sp.* (cattail), *Cladium jamaicense* (sawgrass), *Schoenoplectus californicus* (California bullwhip), *Schoenoplectus robustus* (leafy three-square), and *Juncus roemerianus* (black needlerush).

Historically, the Black Bayou area was in the northern watershed of Sabine basin collecting sheet flow from the surrounding uplands. Black Bayou provided a freshwater head which ran southwest from the uplands near Vinton to the northern rim of Sabine Lake. Beginning in the late 1800s, significant hydrologic changes in the Calcasieu/Sabine basin began affecting water level fluctuation and water circulation patterns in the project area. This has inhibited the freshwater head from flowing north to south and has diverted it to a bidirectional east and west flow via the Gulf Intracoastal Waterway (GIWW) (LCWCRTF 2002). Modifications to Calcasieu Pass such as the removal of the Calcasieu Pass oyster reef (1876) and maintenance of a deep (40 ft) and wide (400 ft) Calcasieu Ship Channel has increased the magnitude and duration of tidal fluctuations causing higher salinity and a broader range of water level fluctuations throughout the lake and the surrounding marshes (LDNR 1993). Construction of the Gulf Intracoastal Waterway, North Line Canal, Central Line Canal, and South Line Canal established an east-west hydrological connection between the previously distinct Calcasieu and Sabine basins, disrupting the natural north-south flow and allowing the saline waters of the Calcasieu Basin to encroach on the Sabine Basin. Water level fluctuations are also highly influenced by local meteorological factors. A strong north wind can cause drastic de-watering of the marshes, while a strong sustained southerly wind can result in drastic increases in water



levels and salinities blown in from the Gulf of Mexico. The extensive system of navigation channels, bayous, oil exploration canals, spoil banks, and trenasses, have allowed increased water fluctuations and salinities to reach the fragile interior marshes in the absence of a strong freshwater head (USDA 1991). Most of the land loss in the project area and surrounding marshes occurred between 1956 and 1978 (Barras et al. 2008), as both large and small scale changes have resulted in local hydrologic alterations. The construction of spoil levees along the GIWW disrupted the drainage of uplands to the north causing communities to create more efficient drainage via conversion of Black Bayou to the Vinton Drainage Ditch (Vinton Water Way) which empties into the GIWW and is diverted away from the project area. The east side of the project area gradually developed into an impoundment over time due to several separate factors in addition to the GIWW dredge levee along the north (originally 1913-14; current dimensions since 1941). There are other hydrologic impediments surrounding the project impoundment such as an oil company access road running east-west along the southern boundary (1950s), landowner boundary levee running north-south on the west side (1968) and the increasing marsh elevations grading into the uplands of the Gum Cove Ridge on the east side.

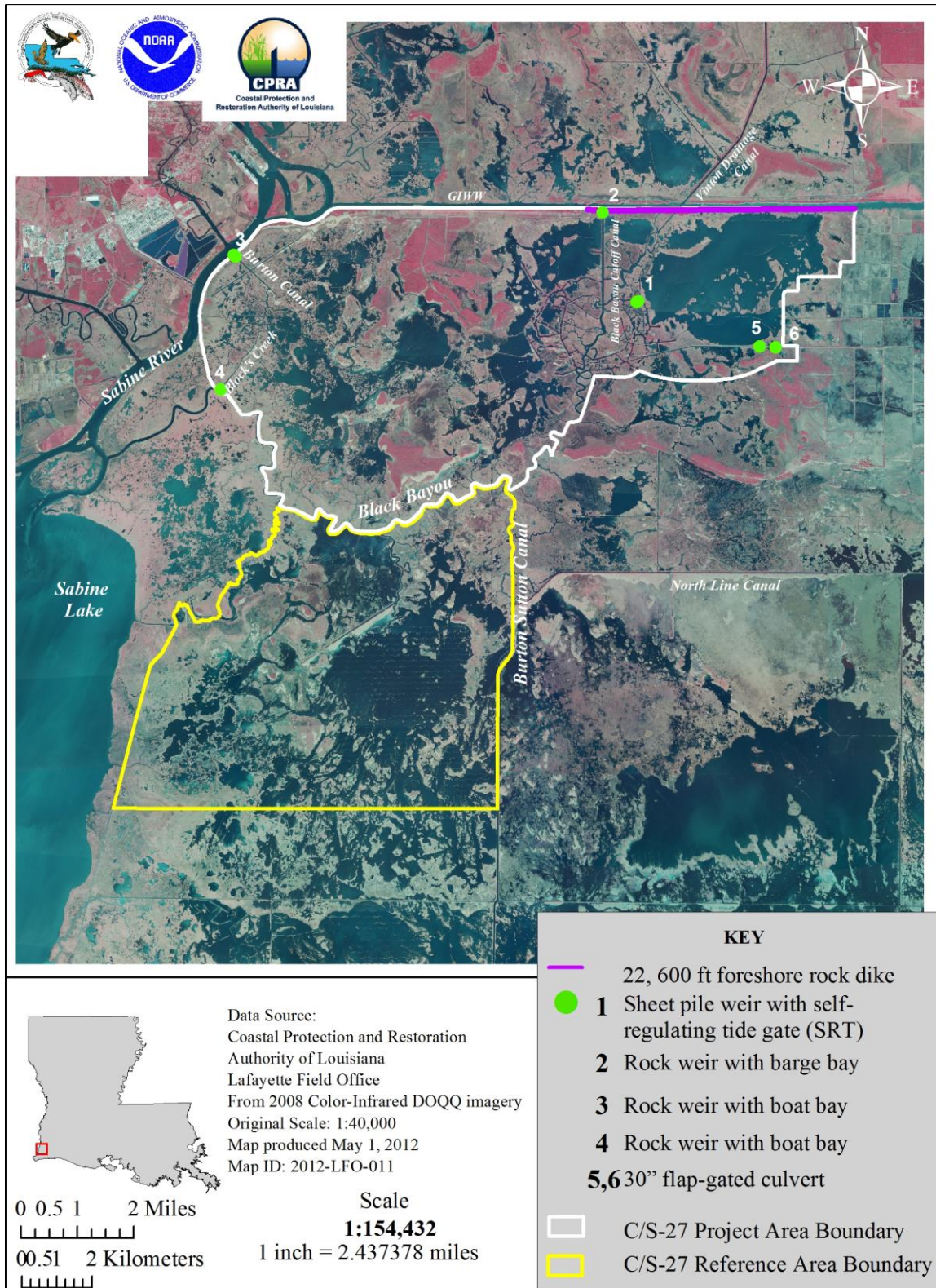
The Black Bayou Hydrologic Restoration Project includes structural and non-structural measures designed to allow freshwater from the GIWW near its confluence with the Vinton Drainage Canal into the wetlands south of the GIWW between the Sabine River, Gum Cove Ridge, and Black Bayou, and to create a hydrologic head that increases freshwater retention time and reduces salt water intrusion and tidal action in the Black Bayou watershed (Figure 1). Black Bayou structural features construction was completed in November 2001. Structural and non-structural features and their intended functions are listed below:

1. Approximately 22,600 linear ft. (6,889 m) of foreshore rock dikes along the GIWW west of the Gum Cove Ridge to repair breaches in the GIWW spoil bank.
2. A weir with a barge bay, 70 ft (21.3 m) wide, with a sill of -7.0 ft NAVD 88, made of graded stone was constructed at the GIWW in the Black Bayou Cut Off Canal to limit water exchange in and out of the project area.
3. A weir with a boat bay, 15 ft (4.6 m) wide with a sill of -4.0 ft NAVD 88, made of graded stone was constructed in the Burton Canal at its intersection with the Sabine River to limit water exchange in and out of the project area.
4. A rock weir with a 15 ft (4.6 m) wide boat bay at - 3 ft NAVD 88 bottom elevation was constructed at the intersection of Block's Creek with Black Bayou to limit water exchange in and out of the project area.
5. A self-regulating tide (SRT) gate, within a sheetpile weir, 40 ft (12.2 m) wide with a sill at + 0.6 ft NAVD was constructed where it connects to an existing canal that leads to Black Bayou Cutoff Canal to limit flow into the impoundment during and increase drainage after high water events. A hinged flap was installed over the weir on either

side of the SRT gate in January 2006 to further limit flow into the impoundment while allowing water to drain out.

6. Two, 30 in (0.76 m) flap-gated culverts (Culvert 1/Culvert 2) were installed along the southeastern boundary of the impoundment in January 2006 to relieve excess waters from the impoundment while preventing water flow into the impoundment.
7. Vegetative plantings of *Schoenoplectus californicus* (bullwhip) in two phases. One gallon trade containers with a minimum of 5 stems per container were installed on 5 ft (1.5 m) centers. Phase I, east side of project area on either side of the Black Bayou Cut-off Canal, contained approximately 30,000 plantings spanning 150,000 linear ft (45,720.5 linear m). Phase II, west side of project area, contained approximately 25,570 plantings spanning 127,850 linear ft (38,969.1 linear m).





**Figure 1.** Black Bayou project and reference boundaries and project infrastructure.

## **II. Maintenance Activity**

### **a. Project Feature Inspection Procedures**

The purpose of the annual inspection of the Black Bayou Hydrologic Restoration Project (CS-27) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs. The annual inspection report also contains a summary of maintenance projects, if any, which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

An inspection of the Black Bayou Hydrologic Restoration Project (CS-27) was held on April 9, 2015 under partly cloudy skies and warm temperatures. In attendance were Stan Aucoin, and Dion Broussard of CPRA. NOAA Fisheries was represented by John Foret. A separate trip was conducted on June 26, 2015 to inspect the culverts under the road on the Gum Cove property. In attendance on this trip were Stan Aucoin, John Foret, and Tim Conner, one of the landowners on the project area. For both trips, parties met at the Lafayette Field Office of CPRA. For the trip to inspect the culverts, parties met Mr. Conner at the Catholic Church in Hackberry and visited the culverts under the road by vehicle. For the other structures, the boat launch in Vinton, LA was utilized. The annual inspection began at the structure on Block's Creek at 12:30pm.

The field inspection included a complete visual inspection of all features. Staff gauge readings were used to determine approximate elevations of water, rock weirs, earthen embankments, steel bulkhead structures and other project features. Photographs were taken at each project feature (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

### **b. Inspection Results**

#### **Block's Creek**

The rock weir seems to be in excellent condition, however landowners indicated that there was some scouring on the inlet and outlet sides of the weir. Upon further investigation, it was found that water was approximately 20 feet deep on the Black Bayou side and approximately 14 feet deep on the inside of the structure. Water depth at the sill is approximately 4.5 feet deep. The two arrow signs on the Black Bayou side of the structure are still missing and will need to be replaced. The erosion on the SE will continue to be monitored, but has stabilized. Navigational lights and signs are inspected quarterly by contractor. (Photos: Appendix A, Photo 1)



### **Burton Canal**

The situation at this weir is the same as at Block's Creek. Water levels on the Sabine River side are approximately 29.5 feet deep and on the inside of the structure, 33.7 feet deep. The sill is at 6.5 feet deep. The scouring along the canal banks inside of the weir at the end of the dike has stabilized. The arrow sign on the SW side of the structure is missing and will need to be replaced. Navigational lights and signs are inspected quarterly by contractor. (Photos: Appendix A, Photo 2)

### **Black Bayou Cut-Off Canal**

Scouring around the structure has occurred here as well. Water depths were 33.5 feet deep on the GIWW side and 23 feet deep on the inside. Sill depth is 10.5 feet. Navigational lights and signs are inspected quarterly by contractor. Coast Guard signs on the inside of the structure were missing at the time of this inspection. (Photos: Appendix A, Photo 3)

### **Self Regulating Tide Gate (SRT)**

The structure is in very good condition. Pillow blocks, signage, railings, wingwalls, etc. remain in excellent condition. The railing along the top of the gate continues to rust and will have to be monitored. The seams at the sheet piles are rusting also, however there is no need for maintenance at this time. Colonies of oysters were noticed on the rocks on the outside of the structure and none on the inside. (Photos: Appendix A, Photos 4-6)

### **Rock Plug**

The rock dike is functioning as designed. Concrete sacks are solid. Tie-ins are stable. No maintenance required. (Photos: Appendix A, Photo 7)

### **GIWW rock dike**

Tie-ins on both the east and west end of the dike are stable. The first and second gaps from the east are solid. The third has a connection through the marsh on the west side that is approximately six feet wide and appears to be fairly deep with significant flow noticed. There is also now a small breach near the fourth plug. As mentioned in previous inspections, the warning signs at both the Vinton and Black Bayou closures have been stolen. The spoil placed behind the rock dike at the Black Bayou Canal has washed away on the western end. Several small gaps along the dike were noticed, however rock is still at the base providing shoreline protection but allowing some exchange to take place. There are a few low spots on the rest of the main dike, apparently caused by barges but these areas are still functioning and not in need of repair. The repair to the dike across from the Vinton Canal with concrete sacks continues to work extremely well. Significant build-up of sediment continues and has become even more apparent between the dike and the shoreline. Emergent vegetation has exploded in large areas behind the dike between the dike and the shoreline. (Photos: Appendix A, Photos 8-12)

### **Culvert 1/Culvert 2:**

These culverts were inspected on June 26, 2015. They appear to be in very good, post construction condition and in no need of repair. No concerns have been expressed by the landowners. (Photos: Appendix A, Photos 13-16)

#### **c. Maintenance Recommendations**

##### **i. Immediate/ Emergency Repairs**

None

##### **ii. Programmatic/ Routine Repairs**

The following items were identified in the 2015 Annual Inspection:

1. Replace stolen warning signs at both the Vinton and Black Bayou closures.
2. Task an engineering firm to evaluate the extent of scouring around the three weir structures and estimate a repair cost.

#### **d. Maintenance History**

**General Maintenance:** Below is a summary of completed maintenance projects and operation tasks performed since December 2003, the construction completion date of the Black Bayou Hydrologic Restoration Project.

**December 2003 - Construction Adjustments:** Although construction of the original project components was completed in December 4, 2001, it was determined that leaks along the GIWW rock dike would have detrimental effects on the project. The rock dike along the GIWW was removed at four separate locations and plugs consisting of “C” stone were constructed at “water” connections between the marsh area and the GIWW existing to the north to reduce or eliminate tidal flow through these locations. The original signs installed at the Black Bayou Cut-Off Structure on timber pilings were either leaning or missing. Signage was relocated on concrete bases on top of the rock weir. Also, at the SRT gate, a railing was constructed on the sheet pile cap to reduce the chance of persons falling into the water in the area around the structure. This work was completed in December 2003 and construction was considered to have been complete after these adjustments.

**July 2003 - Navigational Aid Light Repairs:** A letter was received from the US Coast Guard in July 2003 reporting problems with the navigational lights at the Black Bayou Cut-Off Canal weir. The problem was investigated and repaired in October 2003 by Wet-Tech Energy, Inc. at a total cost of \$1,250.00.

During March 2006, DNR/CED/LFE, via a Purchase Order employed WET TECH Energy, Inc. to inspect and report thereon on damages caused by Hurricane Rita to any of the Navigation Lights and support structures of the Black Bayou Project that were in place as

appurtenant parts of the various structure features of the Project. The cost of the inspection/report was \$2,000.00.

The damages reported were as follows:

- (1) The Black Bayou CutOff Channel west Light needed a new battery box and the replacement of two batteries. The east Light of this site did not need was o.k. and needed no repair.
- (2) The Block's Creek Structure Lights and supports did not need needed no repair work.
- (3) The Burton Canal Structure Light experienced major damage and the entire Light Assembly, Solar Cell, and battery system needed to be replaced.

Later, during May 2006, the damages reported above were all corrected on each respective Structure of the Project by WET TECH Energy, Inc. by a separate Purchase Order for Hurricane Rita Repairs for a total of \$3,842.00. The sum of the costs for the Inspection/Report and thence the repair efforts was \$5,842.00. This entire sum was reimbursed by FEMA for reason of the storm damage.

**July 2005 - SRT Gate modification and culvert installation:** In the spring of 2005, it was determined that water was “stacking up” on the southeast corner of the project area. In order to correct the situation, the cross sectional area of the SRT Gate was increased by attaching a flap to the railing. Also, two 30” flapgated culverts on the southern boundary of the project will relieve excess waters. A Notice to Proceed dated July 20, 2005 was issued to Duphil, Inc. of Orange, Tx. Construction was accepted as complete on January 4, 2006 at a total construction cost of \$84,976.87. Engineering & design, construction oversight, and as-built drawings were provided by C. H. Fenstermaker & Associates at a total cost of \$39,856.77.

#### **Navigational Light Maintenance:**

Automatic Power, Inc. inspects, and if needed, repairs the navigational aid lights at Burton Canal, Block’s Creek, and Black Bayou Cut-Off Canal on a quarterly basis. Costs incurred include:

<b>2007 TOTAL</b>	<b>\$8,000.00</b>
<b>2008 TOTAL</b>	<b>\$6,625.00</b>
<b>2009 TOTAL</b>	<b>\$6,375.00</b>
<b>2010 TOTAL</b>	<b>\$7,340.00</b>
<b>2011 TOTAL</b>	<b>\$7,740.00</b>
<b>2012 TOTAL</b>	<b>\$3,075.00</b>
<b>2013 TOTAL</b>	<b>\$6,427.25</b>
<b>2014 TOTAL</b>	<b>\$1,851.75</b>
<b>2015 TOTAL</b>	<b>\$2,150.00 (As of 2/26/15)</b>

#### **2009 Maintenance Event:**

This maintenance event consisted of general repairs to the flap on the SRT Gate, installation of new, different signs at Burton Canal, and repairs to the closures behind the rock dike as well as a repair to the GIWW dike near Vinton Canal. The work was accomplished by Reeve's Development, Inc. at a total contract cost of \$169,997.18. Engineering, design, and construction oversight was provided by Acadian Engineers & Environmental Consultants, Inc. at a cost of \$46,292.90.

#### **2012 Landowner Event:**

In early 2012, the landowners in the area, under their own construction contract, repaired breaches that had occurred around two of the four plugs behind the rock dike.

### **III. Operation Activity**

#### **a. Operation Plan**

There are no water control structures associated with this project that require manual operation, therefore no Structural Operation Plan is required.

#### **b. Actual Operations**

There are no active structural operations associated with this project.

### **IV. Monitoring Activity**

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the CS-27 Monitoring Plan to merge it with CRMS and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are four CRMS sites located in the project area (CRMS0658, CRMS0662, CRMS0663, and CRMS2166), and three located outside the project area used as reference locations in similar marsh habitat (CRMS660, CRMS0665, and CRMS2189).

#### **a. Monitoring Goals**

The objectives of the Black Bayou Hydrologic Restoration project are:

1. Increase freshwater retention that reduces salt water intrusion in the project area.
2. Establish emergent wetland vegetation in shallow open water areas.
3. Protect emergent marsh in project area by reducing erosion along GIWW.
4. Increase occurrence of SAV in project area.

The following goals will contribute to the evaluation of the above objectives:

1. Reduce mean salinities within the project area.
2. Increase the land to water ratio within the project area.
3. Reduce mean erosion rate of protected shoreline along GIWW.
4. Increase SAV in interior ponds within the project area.

## **b. Monitoring Elements**

### **Aerial Photography**

Near-vertical color-infrared aerial photography (1:24,000 scale) was used to measure vegetated and non-vegetated areas for project specific project and reference areas. The photography was obtained in November 2000 prior to project construction and post-construction in November 2004 and 2010. The original photography was checked for flight accuracy, color correctness, and clarity and was subsequently archived. Aerial photography was scanned, mosaicked, and georectified by U.S. Geological Survey at the National Wetlands Research Center (USGS/NWRC) personnel according to standard operating procedures to develop land:water analyses (Steyer et al. 1995, revised 2000). Differences in percent land over time within the project and between the project and reference areas are calculated from the land and water analyses.

Aerial photography (color infrared, CIR) and satellite imagery (Landsat Thematic Mapper, TM) have been collected for the entire coast through CRMS. The aerial photography is analyzed for CRMS stations at one meter resolution. The satellite imagery is analyzed to determine land and water areas for the entire coast. This imagery will be a subset and used to evaluate changes in land and water areas within the CS-27 project area at a coarse (30m) resolution. The CRMS spatial viewer provided historic data for land water quantification in the project area starting in 1956. The years analyzed for land water quantities through the CRMS viewer were 1956, 1978, 1988, 2004, 2006, and 2008. The data provided by this tool is at a large spatial scale and is designed to show trends in land loss, not exact acreages or locations.

### **Salinity**

Salinity data from both discrete (YSI 30) and continuous recorder (sonde) stations were monitored to characterize the spatial variation in salinity throughout the project area and to determine if salinity was reduced in the project area. Discrete salinities were monitored: (A) monthly from June 1999 (preconstruction) through March 2004 (post construction) at designated stations throughout the project and reference area (Figure 2) and (B) during submerged aquatic vegetation surveys in the fall of 1999, 2003, 2005, 2007, 2012 and 2014. In addition, two discrete surface water salinity stations are providing data inside and outside of project structures during sonde servicing beginning in March 2012 through present. Discrete porewater from the soil salinity at 10 and 30 cm was collected at all of the vegetation plots during vegetation sampling. Porewater was extracted with a sipper tube assembly (rigid



aquarium tubing, flexible hose, and syringe), and salinity was measured using a hand held salinity meter (YSI 30 Salinity, Conductivity, Temperature Meter).

Hourly salinity and water levels (ft, NAVD88) were monitored with a continuous recorder in the impoundment side of the SRT gate (station CS27-25) from May 2000 to present. Salinity data is also currently being monitored hourly utilizing three CRMS-Wetlands stations (658, 662, and 663) within the project area and selected reference sites (660, 665, and 2189). Continuous data were used to characterize average annual salinities throughout the project and reference areas. Salinity data collection from the discrete stations and a continuous recorder (station CS27-22) was discontinued in March 2004 to be replaced by CRMS-Wetlands stations. Continuous recorders were deployed within the project area starting in February 2008 (CRMS0658 replaced CS27-22).

### **Vegetation Plantings**

*Schoenoplectus californicus* (California bullwhip) plantings were installed in 2002 and 2003 to establish emergent wetland vegetation in shallow open water areas within the project area. These plantings took place in two phases; Phase I was completed in May 2002 in the east side of the project area (~ 7 acres), and Phase II was completed in May 2003 in the west side of the project (~ 6 acres). The percent survival of vegetative plantings in phase I was determined after one growing season post construction (2003) in approximately 3% of the vegetation plantings (53 sampling plots). Each sampling plot consisted of 16 plantings from one row with the sampling location determined by a random numbers table and marked with a labeled post. Planting survival was determined as a percentage of the number of live plants to the number initially planted (percent survival = (no. live plants/no. planted) × 100) (Mendelssohn and Hester 1988; Mendelssohn et al. 1991). No further monitoring of the plantings is scheduled.

### **Shoreline Change**

To document the effectiveness of the foreshore rock dike to reduce erosion and protect the emergent vegetation in the breached areas of the impoundment along the GIWW, shoreline surveys were conducted using a sub-meter differentially corrected Global Positioning System (dGPS) to map the vegetated edge. Surveys were conducted 1.66 years preconstruction in March 2000, immediately (4 months) post-construction in March 2002, and 2.75 years post-construction in August 2004. Analyses of shoreline change were performed by digitally overlaying mapping clean line features for each dataset in a Geographic Information System (GIS, ArcGIS). Polygon features were then created for all areas within closed intersections of the two polyline datasets. The generated polygon features represent the total change in land area as defined by the difference in shoreline position during the sampling interval. The total area for all polygons between the line features was calculated and each polygon feature was defined as gain or loss. The total land area in acres of gain and loss was then calculated. The reference area shoreline was compromised because of another rock dike construction during the time between the 2000 and 2002 GPS surveys and therefore, we evaluated only the project shoreline change over time. The data is presented in two increments, pre- to immediately post-construction (2000-2002) and post construction (2002-2004). No additional shoreline surveys are scheduled.

### **Submerged Aquatic Vegetation (SAV)**

To document changes in the occurrence of SAV, project areas (1-6) and a reference area were monitored over time using the modified rake method (Chabreck and Hoffpauir 1962) (Figure 3). Three transects oriented northeast to southwest were established across open water in each area. Submerged aquatic vegetation was sampled repeatedly along each transect by dragging a rake on the pond bottom for one second. The presence or absence of vegetation was recorded for each sample to determine the percent occurrence on a transect (% occurrence = (number of samples with SAV/number of samples) × 100). When vegetation was present, the species present was recorded in order to determine the frequencies of individual species (Nyman and Chabreck 1996). SAV was monitored before construction in fall 1999 and after construction in fall 2003, 2005, 2007, 2010, 2012 and 2014. SAV monitoring will continue in fall of 2017.

### **Emergent Vegetation:**

Vegetation composition and cover was estimated from 10 permanent 2x2 m plots that are randomly distributed along a transect in the emergent marsh within each of the 1 km<sup>2</sup> CRMS-Wetlands sites. Data was collected at four CRMS stations located within the CS-27 project area (658, 662, 663, and 2166) and three selected reference sites (660, 665, and 2189) in the reference area. Emergent vegetation parameters will be evaluated at each CRMS site using techniques described in Steyer et al. (1995) to describe species composition, richness, and relative abundance; in addition, overall percent cover and height of the dominant species will be monitored. Annually at each site, data will be collected and averaged from ten, 4-m<sup>2</sup> sample plots randomly established along a 282.8 m transect that crosses diagonally through a 200m × 200m vegetation plot in middle of the CRMS site. The percent cover of the plot and of each species was fed into a floristic quality index based on the marsh type the data was collected. Floristic Quality Indices (FQIs) have been developed for several regions to determine the quality of a wetland based on its species composition (Cohen et al., 2004; Bourbaghs et al., 2006). This FQI was developed by Jenneke Visser and an expert panel on Louisiana coastal vegetation as part of CRMS analytical working group in 2007, revised 2011 (Cretini et al., 2011). The panel provided an agreed upon score (Coefficient of Conservatism or CC Score) from 0 to 10 for each species in a list of ~500 plant species occurring in Louisiana's coastal wetlands (Table 1). CC scores are weighted by percent vegetative cover and summed to determine the FQI for the CRMS site.

**Table 1.** Coefficient of Conservatism (CC) scores of different plant species used to develop of a Floristic Quality Index.

CC Score	General Description	Coastal Louisiana Description
0	Alien taxa or native invasive species	Invasive or non-native plants
1-3	Wide spread taxa found in sites with different levels of disturbance	Opportunistic plants of disturbed areas
4-6	Taxa that display fidelity to a community but can tolerate moderate disturbance	Occur primarily in less vigorous coastal wetland communities
7-8	Taxa that are typical of communities which	Common plants in vigorous coastal

	have sustained only minor disturbance	wetland communities
9-10	Taxa that exhibit a high degree of fidelity to a narrow set of ecological conditions	Dominant plants in vigorous coastal wetland communities

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### **Hydrologic Index**

The Hydrologic Index (HI) assesses the relationship between the combined effect of mean salinity and percent time flooded on vegetation primary productivity for 5 different marsh classifications in coastal Louisiana (swamp, fresh, intermediate, brackish, and saline). The index score ranges from 0 - 100, representing the percent of maximum vegetation productivity expected to occur if the separate effects of salinity and inundation on productivity interact in a multiplicative fashion.

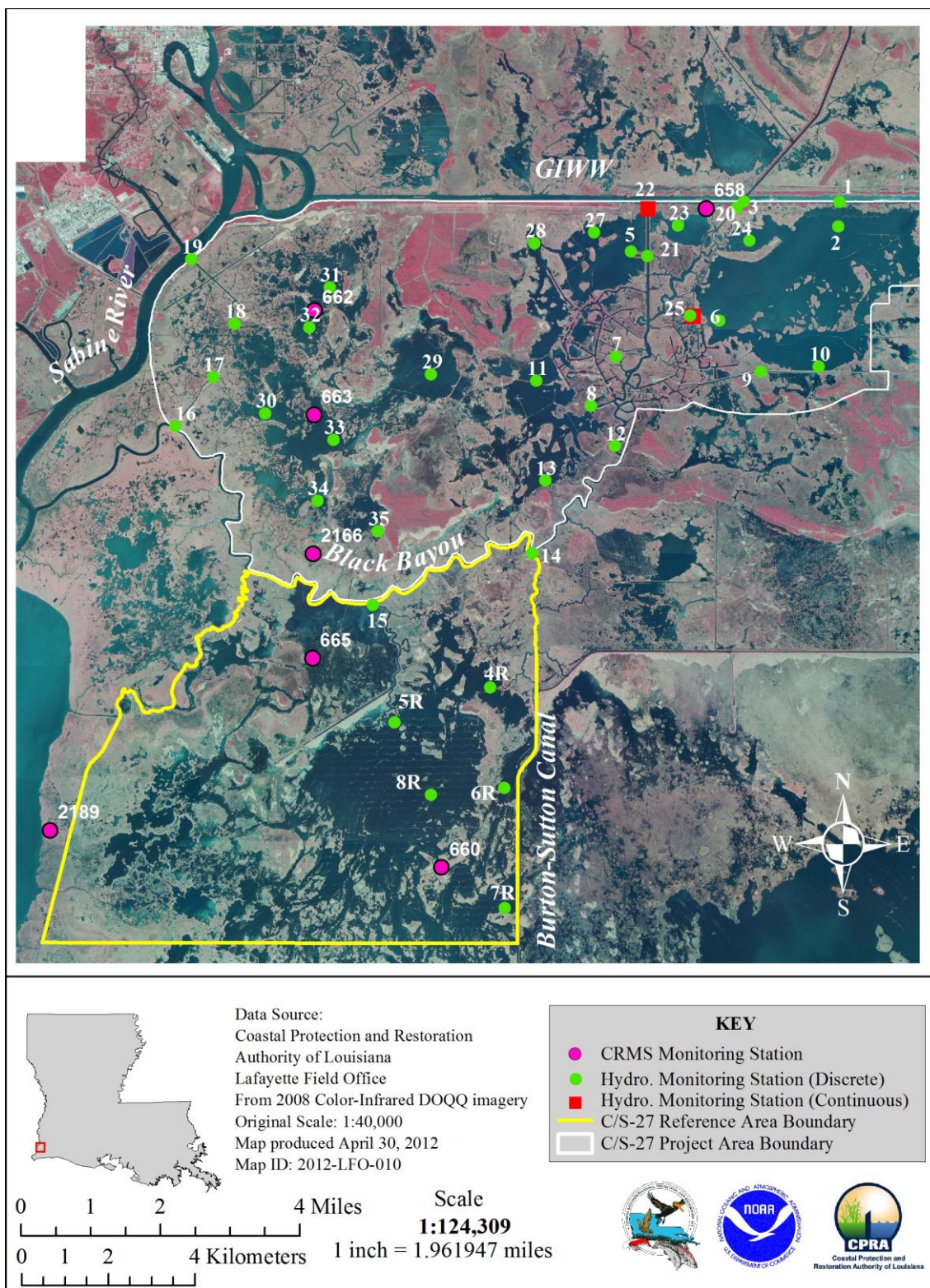
### **Soil Properties**

Soil cores were collected to describe major soil properties such as bulk density and percent organic matter. Three, 4" (10.16-cm) diameter cores were collected to a depth of 24 cm and divided into 6, 4-cm sections at each site. The soil was processed by the Department of Agronomy and Environmental Management at Louisiana State University. Soil cores were only collected at the project and reference CRMS sites during station establishment in 2005-2007 and the second series of samples has not yet been collected. Cores were collected at four sites inside the project area, and suitable cores (quality or same marsh type) were collected from two sites outside the project area.

### **Soil Surface Elevation Change**

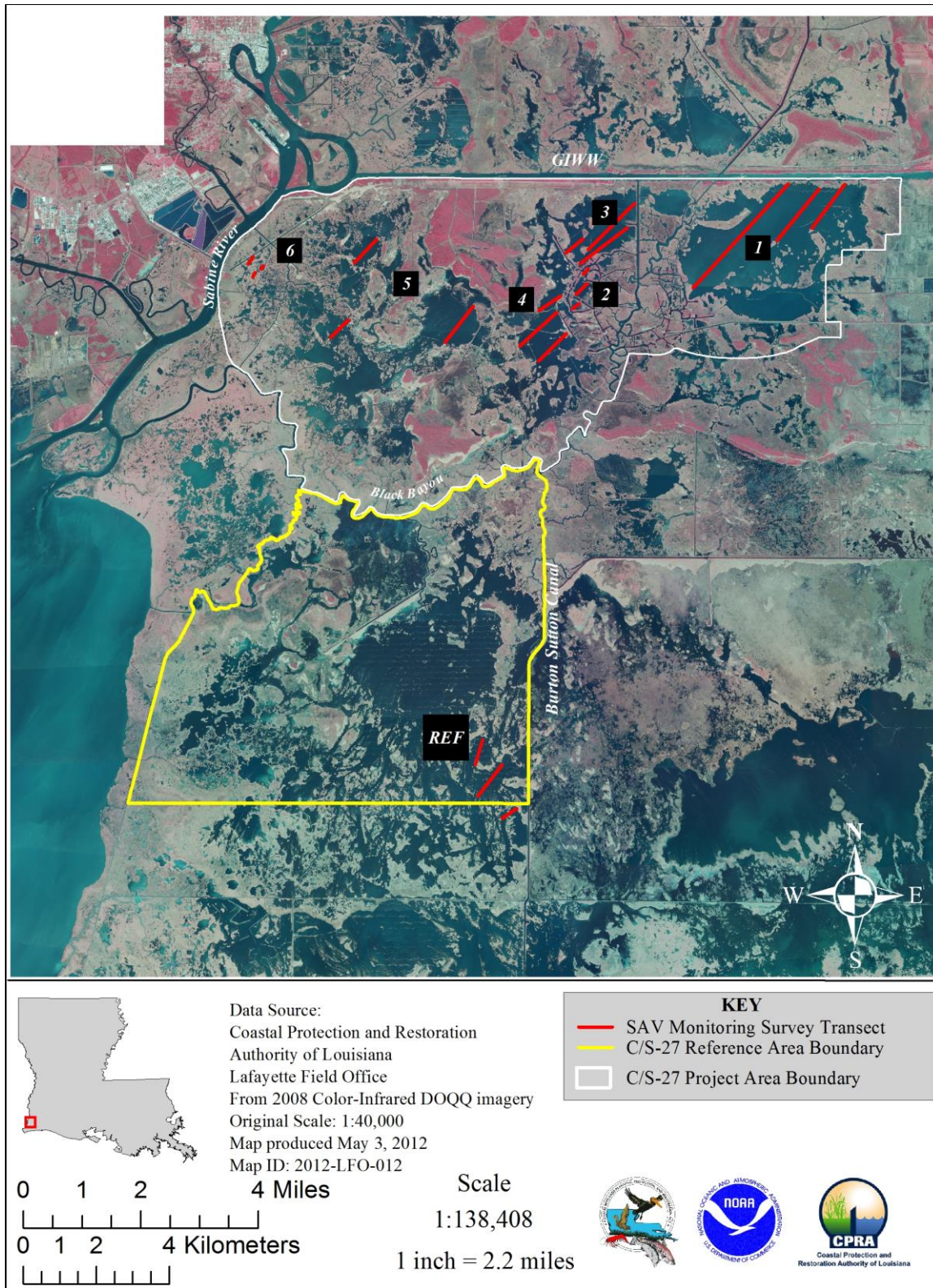
Soil surface elevation change utilizing a combination of sediment elevation tables (RSET) and vertical accretion from feldspar horizon markers are being measured twice a year at each of the project and reference CRMS sites. These data will be used to describe the general trends in elevation change and establish accretion/subsidence rates. The RSET was surveyed to a known elevation datum (ft, NAVD 88) so it could be directly compared to other elevation variables such as water level. Data collected over at least 5 years was used to calculate rates for the project and reference area; therefore the displayed elevation change rates are an estimation of that temporal trend.





**Figure 2.** CS-27 continuous recorder station, discrete salinity stations, and CRMS sites located within and the project and reference areas.





**Figure 3.** Location of the submerged aquatic vegetation (SAV) sampling transects in the CS-27 project and reference areas.



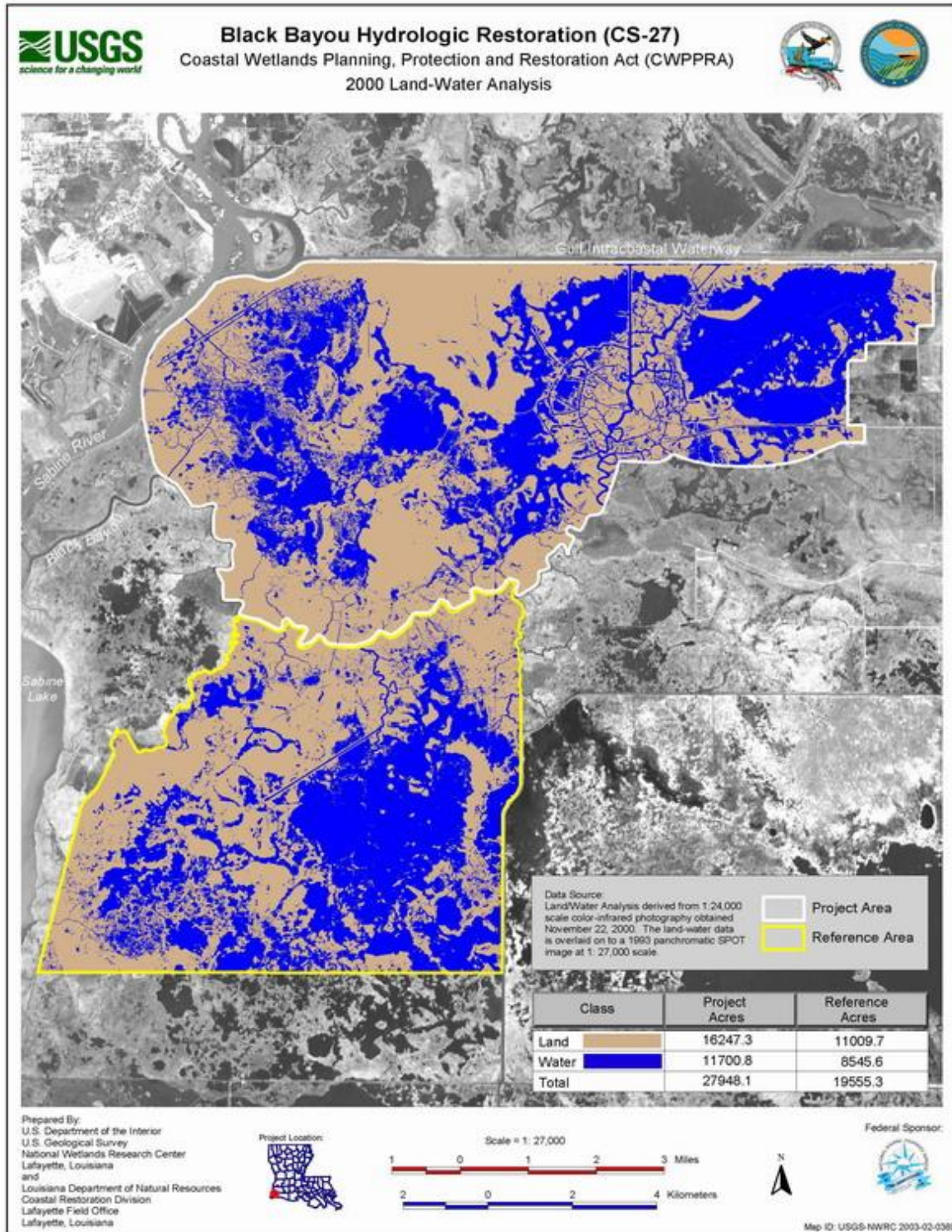
#### **IV. Monitoring Activity (continued)**

##### **c. Monitoring Results and Discussion**

###### **Aerial Photography**

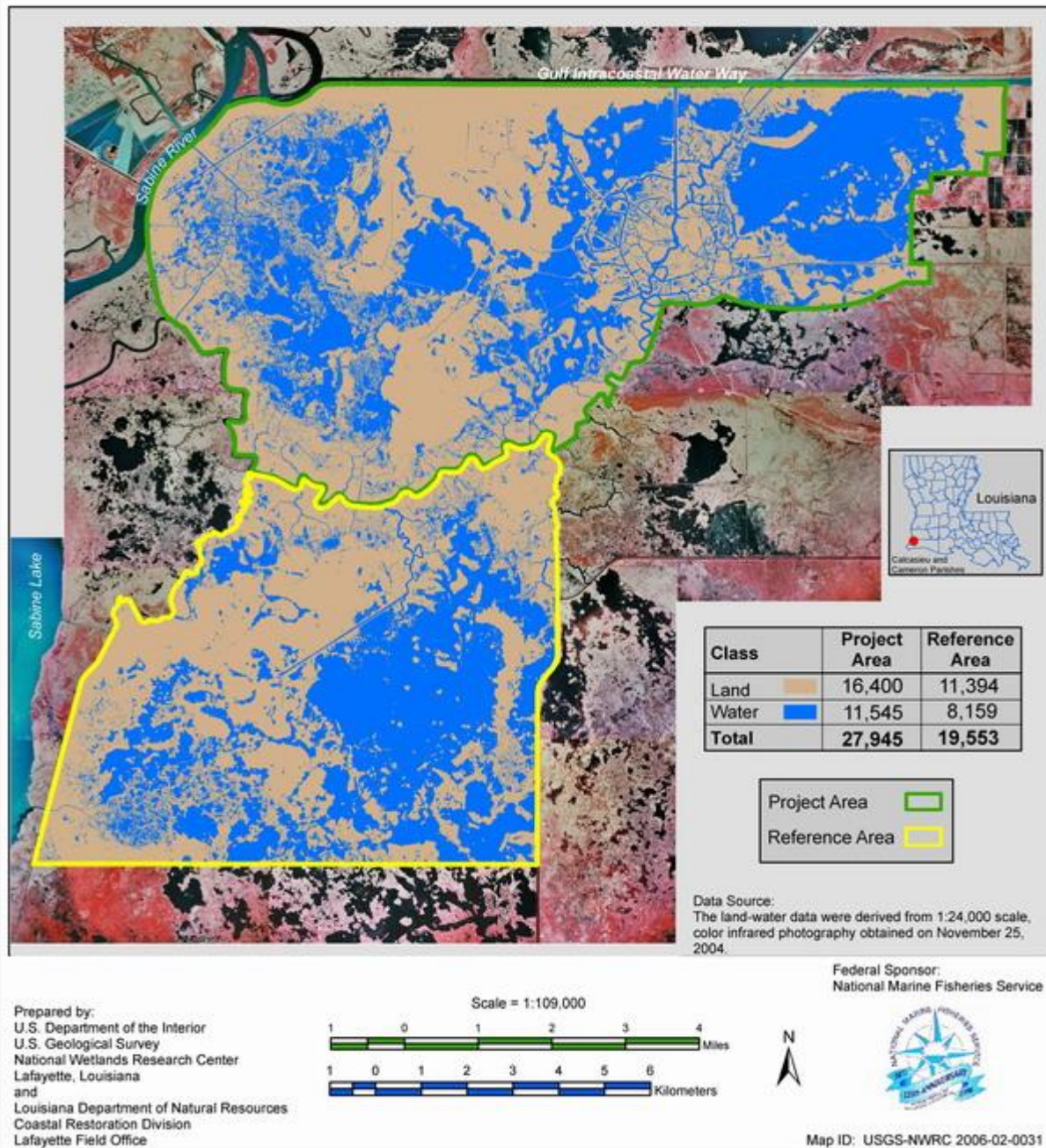
Land and water aerial photography was acquired and analyzed before construction in November 2000 and after construction in November 2004 and November 2010 by the U.S. Geological Survey (Figures 4a-c). The project area gained 153 acres (0.6%) of land from 2000 to 2004 (1 year pre-construction to 3 years post-construction) (Table 2). During this same time, the reference area gained 384 acres (2%) The difference in the 2000 to 2004 time period suggests the entire area was becoming more vegetated and the higher rate of land gain in the reference area suggests this change was not due to project features.

From 2004 to 2010, the project area lost 163 acres of land or -0.6% while the reference area lost 1168 acres or -6%. Landloss from 2004 to 2010 was almost certainly due to Hurricanes Rita (2005) and Ike (2008). Hurricane Rita was more associated with sediment deposition in the CS-27 project and reference areas, as well as the surrounding region. It is believed that Hurricane Rita did not significantly reduce land area in either the project or reference area due to the deposition of sediment removed from areas further south. Conversely, Hurricane Ike was associated with large areas of marsh scour, resulting in shallow open water (Figure 5). Field observations after Hurricane Ike in the CS-27 reference area showed areas of marsh scoured by the storm, and later marsh die-off in fresher areas due to the influx and retention of high salinity water from the storm surge. A similar effect was not seen in the CS-27 project area. If most of the land loss in the reference area was due to storm surge scour from Hurricane Ike, the difference in the project area may be due to the greater distance from the Gulf of Mexico and the presence of the GIWW levee which, judging by the location of wrack fallout, appears to have greatly reduced the energy of the storm surge, thus reducing scour and sediment displacement. Project features may also have played a part in the months following the storms, as the reduction of rapid water exchange may have allowed for greater recovery of affected vegetation and the deposition of suspended sediments. The reduction in exchange may have allowed vegetation to recover. Overall, from 2000-2010, marsh loss was less in the project area than the reference area (Table 2). The larger scale CRMS coastal satellite TM land water analysis strongly concur with the project specific percentages of land water and the overall stability of the project area percent land (Figure 6). These values for the same time frame as described at the project scale were very consistent to those in table 2 between 60% and 65% land for the decade between 2000 and 2010 with a small positive slope.



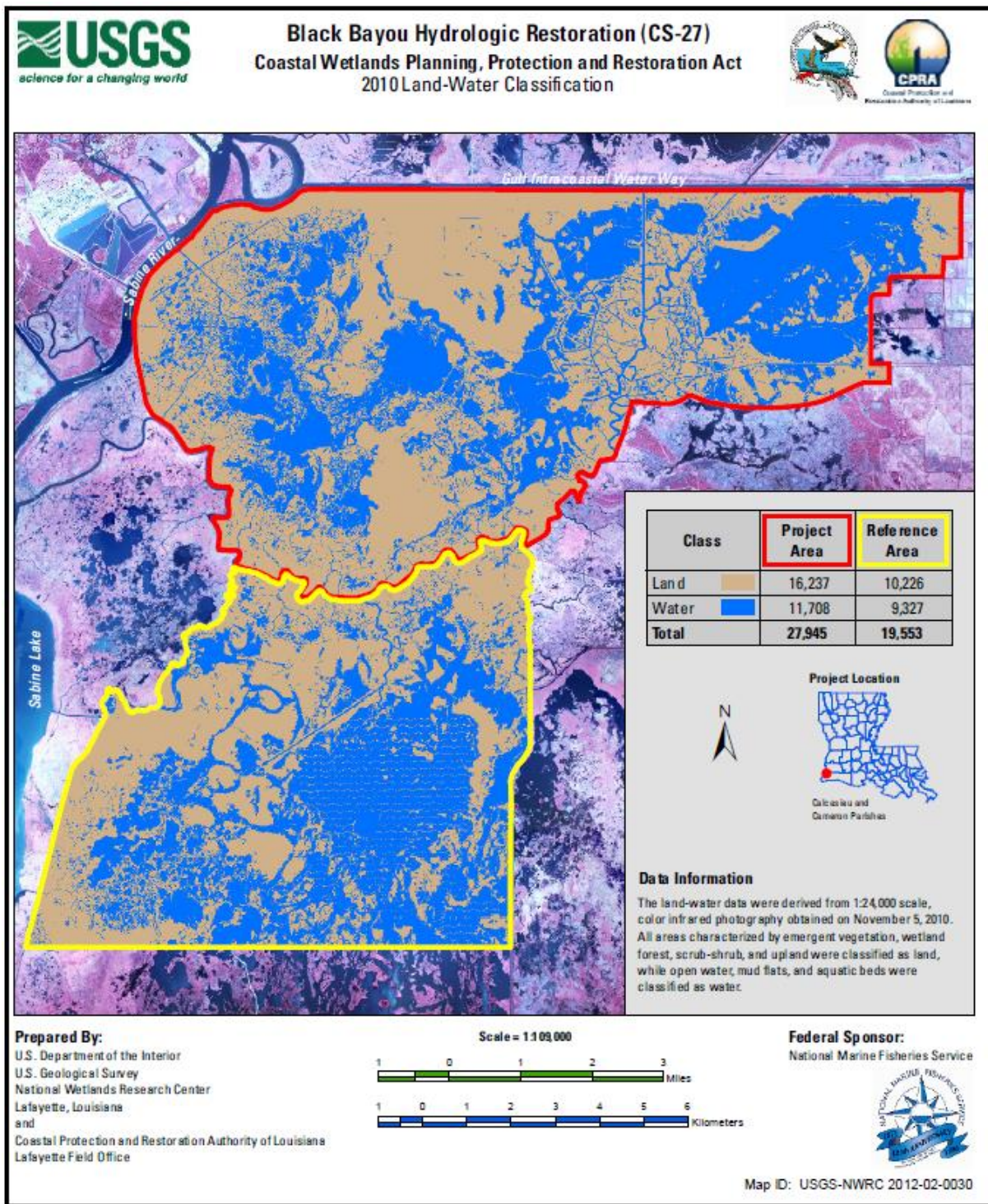
**Figure 4a.** Preconstruction land water analysis of CS-27 project and reference areas from photography taken November 20, 2000.





**Figure 4b.** Post construction land water analysis of CS-27 project and reference areas from photography taken November 25, 2004.





**Figure 4c.** Post construction land water analysis of CS-27 project and reference areas from photography taken November 5, 2010.





**Figure 5.** Area of marsh converted to open water by hurricane scour in the Calcasieu Sabine basin near CS-27.

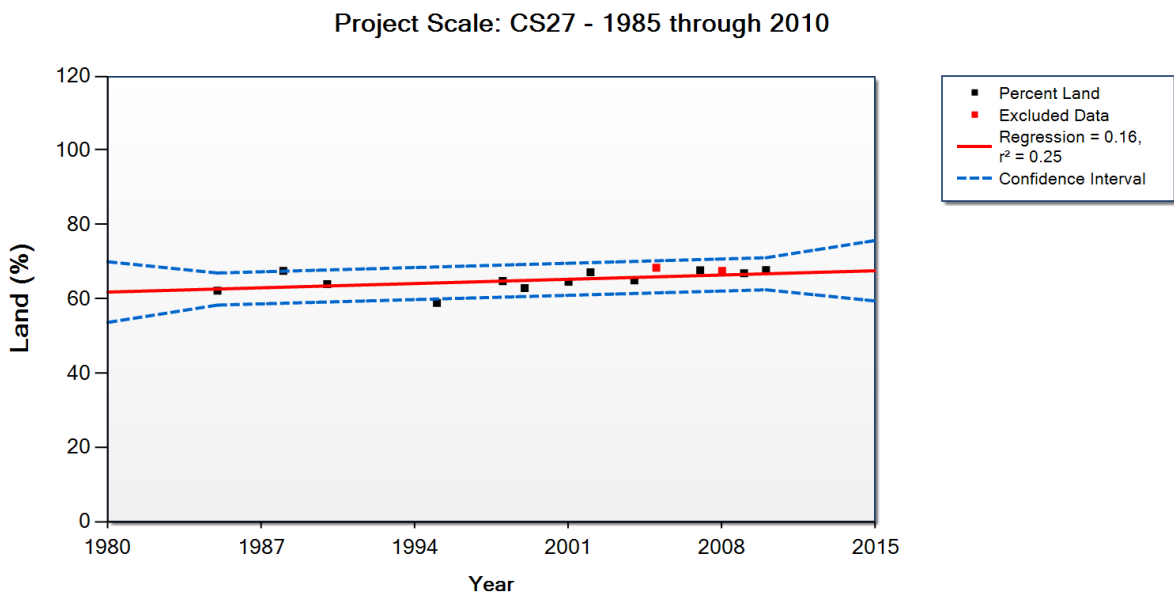


**Table 2.** Land area and change rates compiled from high resolution imagery (1:24,000) collected by the USGS-National Wetlands Research Center pre- (2000) and post-construction (2004, 2010) of CS-27. Initial construction was completed in November 2001; Hurricane Lili occurred in October 2002, Hurricane Rita occurred in September 2005, and Hurricane Ike occurred in September 2008.

	Project Area					
	2000		2004		2010	
	acres	%	acres	%	acres	%
Land	16,247.3	58.1	16,400.0	58.7	16,237.0	58.1
Water	11,700.8	41.9	11,545.0	41.3	11,708.0	41.9
Total	27,948.1		27,945.0		27,945.0	

	Reference Area					
	2000		2004		2010	
	acres	%	acres	%	acres	%
Land	11,009.7	56.3	11,394.0	58.3	10,226.0	52.3
Water	8,545.6	43.7	8,159.0	41.7	9,327.0	47.7
Total	19,555.3		19,553.0		19,553.0	



**Figure 6.** Project scale percent land analysis within the CS-27 project area (n=12) for years 1985 to 2010 with projected percent land estimate through 2015 (CRMS spatial viewer land/water, Barras et al. 2008).

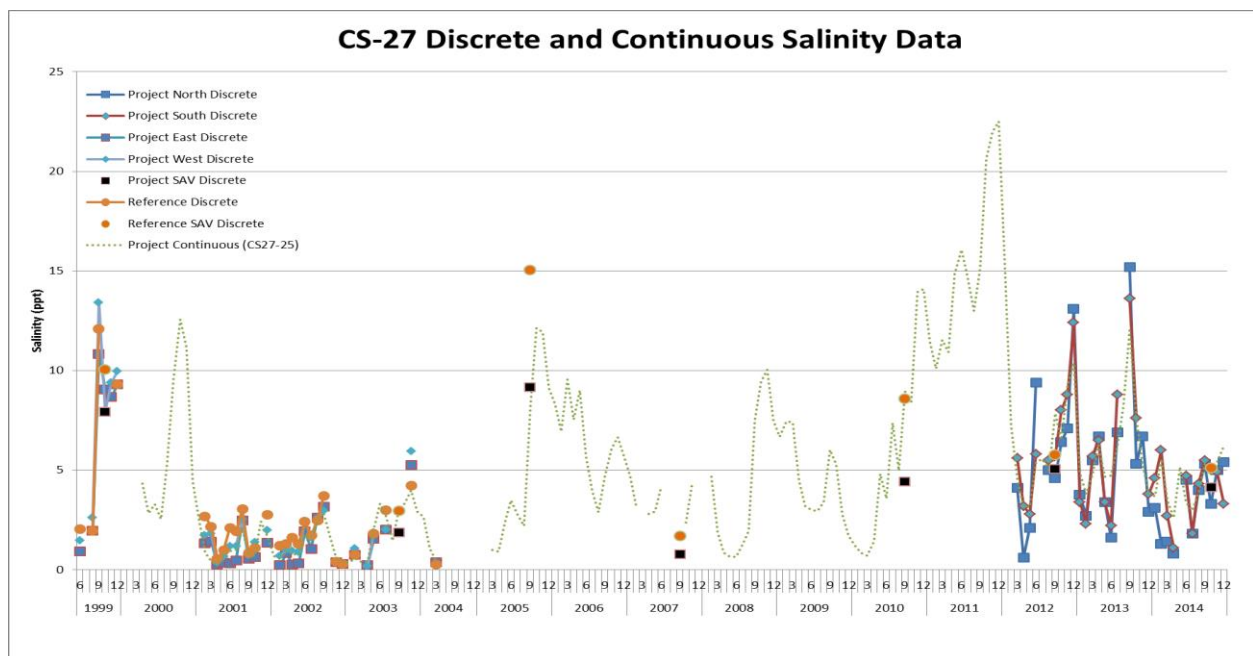
## **Salinity**

Discrete salinity data was collected monthly throughout the project and reference areas for the period 1999-2004. Data was divided by region (east and west of Black Bayou Cutoff Canal (BBCC)) in the project area (Figure 7). The east and west regions of the project areas were similar in salinity during the collection period. The reference area generally exhibited the same salinity pattern as the project. The salinity spike during 1999-2000 was due to drought conditions, reducing the influx of fresh water to the project and reference areas and allowing saltwater entry from Black Bayou, the GIWW, and the Sabine River (<http://www.drought.noaa.gov/index.html>). Most discrete salinity stations showed this salinity spike, with the spike reaching a higher peak salinity in the western project area than of the eastern project or reference areas. Between 2001 and 2003 salinities were very low, ranging from 0 to 5 ppt in the project and reference area, among the lowest span measured via discrete or continuous methods. There are currently two project specific discrete salinity stations monitored when the project specific continuous recorder CS27-25 is serviced approximately monthly. These are located at CS27-14 on the southern end of the project area and at CS27-3 on the northern end of the project area. This data has been collected from 2012-2014 and is very similar to the continuous recorder CRMS0658 and CS27-25 data over the same period. Also discrete salinity measurements are collected during SAV sampling and offer an additional opportunity to examine salinity. These SAV discrete measurements generally agree with other methods of salinity data collection.

Continuous salinity within the northeast portion of the project area, which is mostly influenced by the BBCC structure, the self-regulating tide gate, and foreshore dike along the GIWW, was monitored from 2000 to 2004 inside (Station CS27-25) and outside (CS27-22) of the impoundment (Figure 8). Weekly average salinity was not significantly different between the inside and outside of the impoundment either pre- or post-construction ( $\chi^2=2.85$ ,  $p=0.0927$ ). Station CS27-22 was abandoned in March 2004 and was replaced by CRMS0658 in 2008 while station CS27-25 remains in place through present. For the period 2008-2014, station CS27-25 was compared to CRMS station 658 to determine if a difference in salinity occurred between the inside and outside of the impoundment by year. An analysis of the continuous data determined that during the prolonged drought 2011 was significantly more saline than any other year measured ( $F_{6,741}=120.4$ ,  $p<.0001$ ) (Figure 9). The weekly mean difference in salinity inside and outside of the impoundment was only marginally different in 2011 and was not different in any other year (weekly means  $n=52$ ,  $\chi^2=3.25$ ,  $p<.0713$ ). But under normal conditions the inside of the impoundment is very similar to the outside of the impoundment, suggesting that consistent hydrologic separation is not maintained. Water exchanges via the overtopping of the SRT gate and through the multiple rock plugs in the GIWW spoil bank and the rock plug near the SRT gate. This exchange is extremely limited compared to the pre project conditions and the exchange rates of water and organic material is substantially reduced. However the salinity similarity inside and outside of the freshwater impoundment shows enough exchange takes place to keep salinity comparable in both locations.

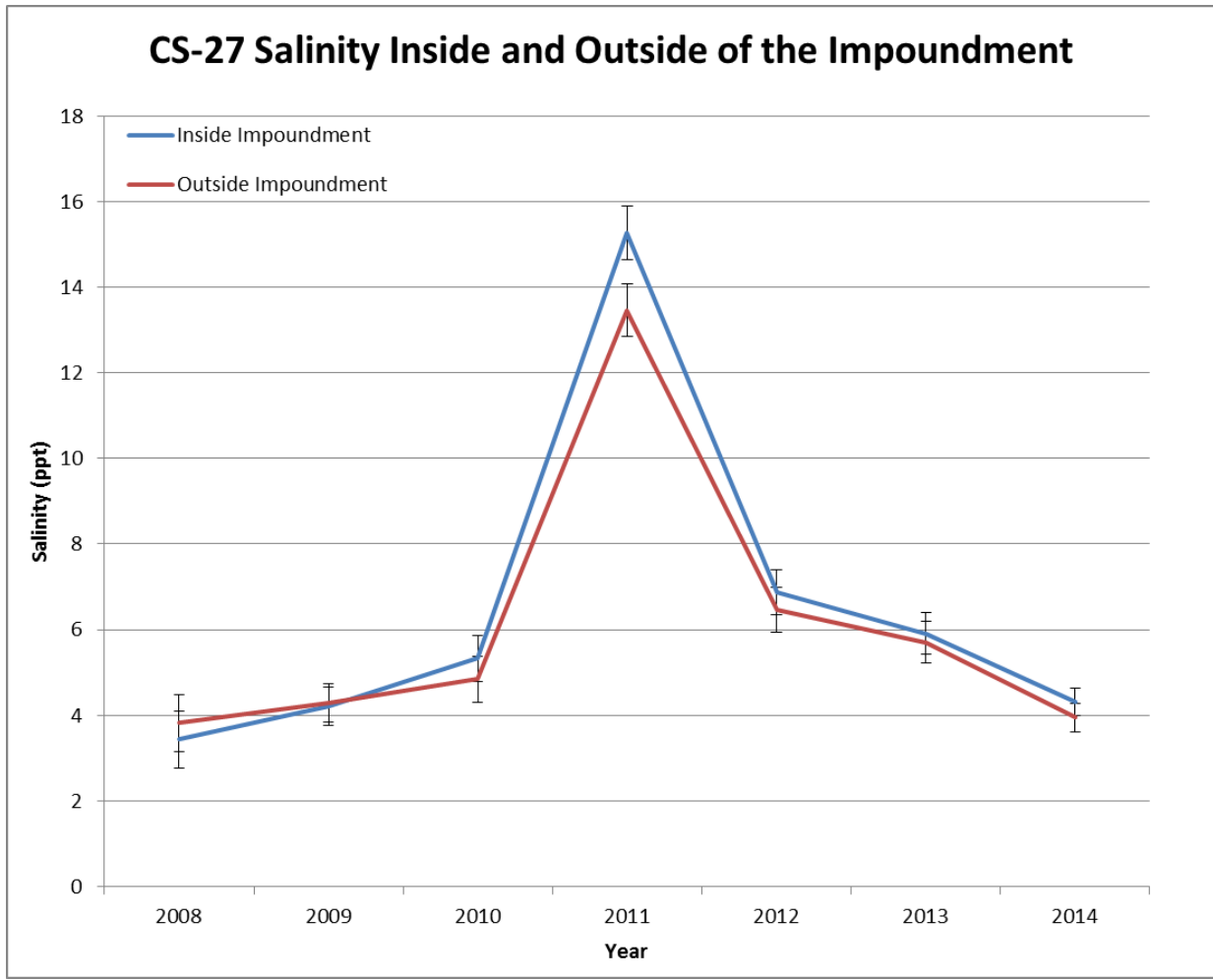
The project area (CRMS0658, CRMS0662, and CRMS0663) continuous salinity stations have generally recorded lower average monthly salinity values since installation in 2008 than the

reference stations (CRMS0660, CRMS0665, and CRMS2189) (Figure 10). This effect was specifically evident during several salinity spikes highlighted around Hurricane Ike when the project area salinity was on average half that of the reference area for more than two years. This salinity gradient between the project and reference area homogenized as a result of the 2011 drought and the project area did not begin to experience fresher conditions compared to the reference area until the end of 2013 through 2014. This indicates the effectiveness of the project features in preventing saltwater intrusion into the project area even under tropical storm conditions. The projects effectiveness was muted by the drought during 2011 likely due to the lack of a fresh water head to the north and the extreme salinity experienced in the Cal/Sab basin which was nearly twice the average of salinity spikes brought on shore by Hurricanes Ike and Rita in the project area. One purpose of the hydrologic management in this project is to maintain low salinities in order to allow marsh vegetation to establish and flourish. Porewater collected from the soil at CRMS sites provide a direct measurement of the salinities that the plant roots are exposed to at 10 and 30 cm (~ 4 and 12 inches) below the soil surface. Porewater salinities were very similar in the project and reference areas. Porewater salinities tracked the surface water salinity data very closely peaking in 2011 and dropping precipitously in 2012 through 2014.



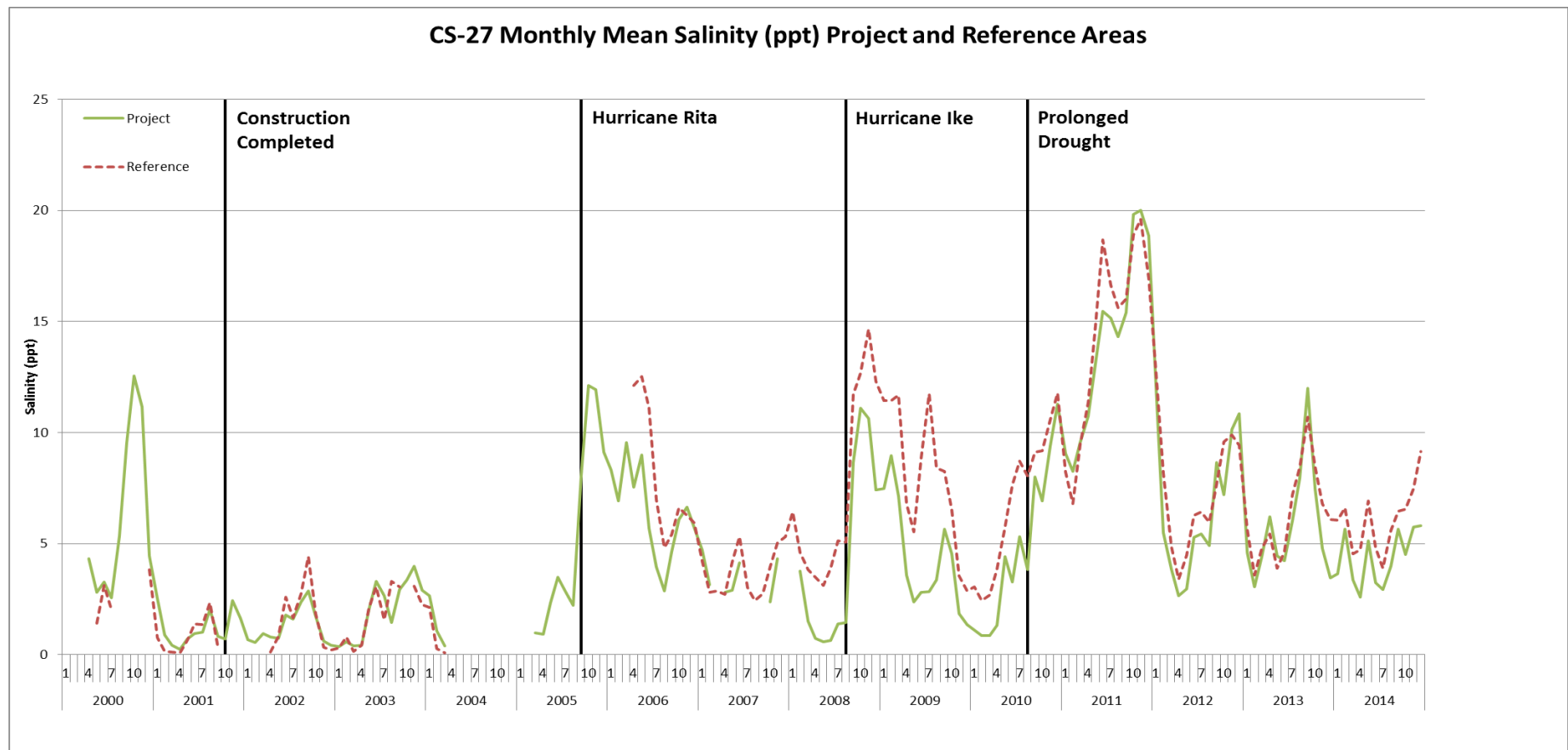
**Figure 7.** Discrete open water salinity measurements collected in the project (east and west) and reference areas during the period 1999-2004 and north and south 2012-2014, and during SAV sampling with CS27-25 continues monthly means.





**Figure 9.** Yearly means and standard errors of continuous salinity collected at project stations CRMS0658 (outside impoundment) and CS27-25 (inside impoundment) from 2008-2014.





**Figure 10.** Monthly means of continuous salinity collected at stations in the project (CS27-25, 658, 662, 663) and reference (660, 665, and 2189) areas from 2000-2014. Construction of structures to control water flow into the project area and to create the impoundment was completed in November 2001.

### **Vegetation Plantings**

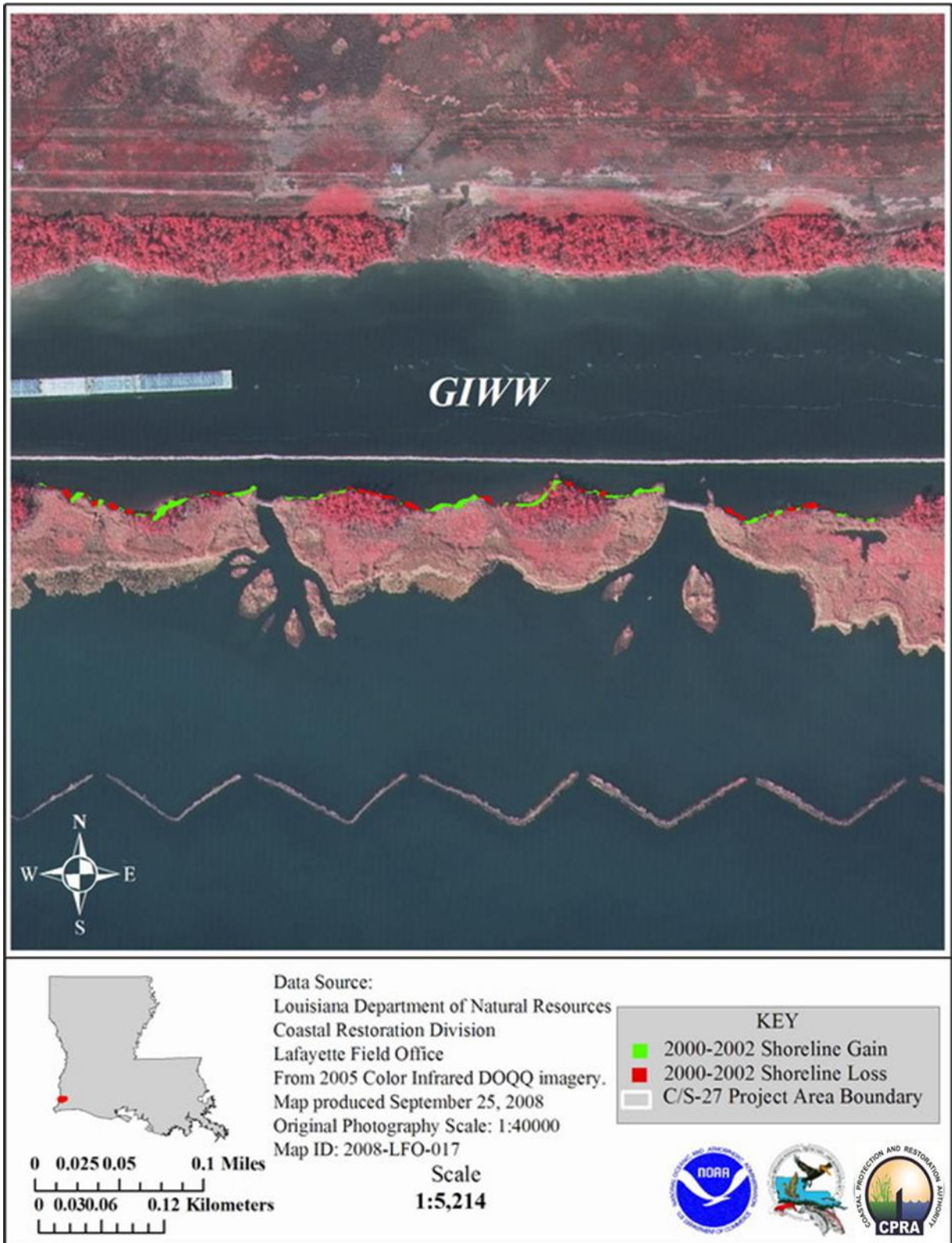
*Schoenoplectus californicus* (bullwhip) plantings were installed on the east side (Phase I – 2002) and on the west side (Phase II – 2003) of the project area. Monitoring was conducted in September approximately 1 year after Phase I planting. Sample plots had varying survival success. Individual plantings were recorded as alive, absent, or dead. Except for a few, most plants counted as absent or dead were absent. A total of 53 plots containing 848 plants were sampled. The mean percent survival was 68% ranging from 100% to 6% survival depending on location. Some plots had robust, healthy plants that were almost indistinguishable from one another, whereas other plots had plants with few stems in deteriorated condition (LDNR 2004). Similar observations were noted about the Phase II planting in spring 2008.

### **Shoreline change**

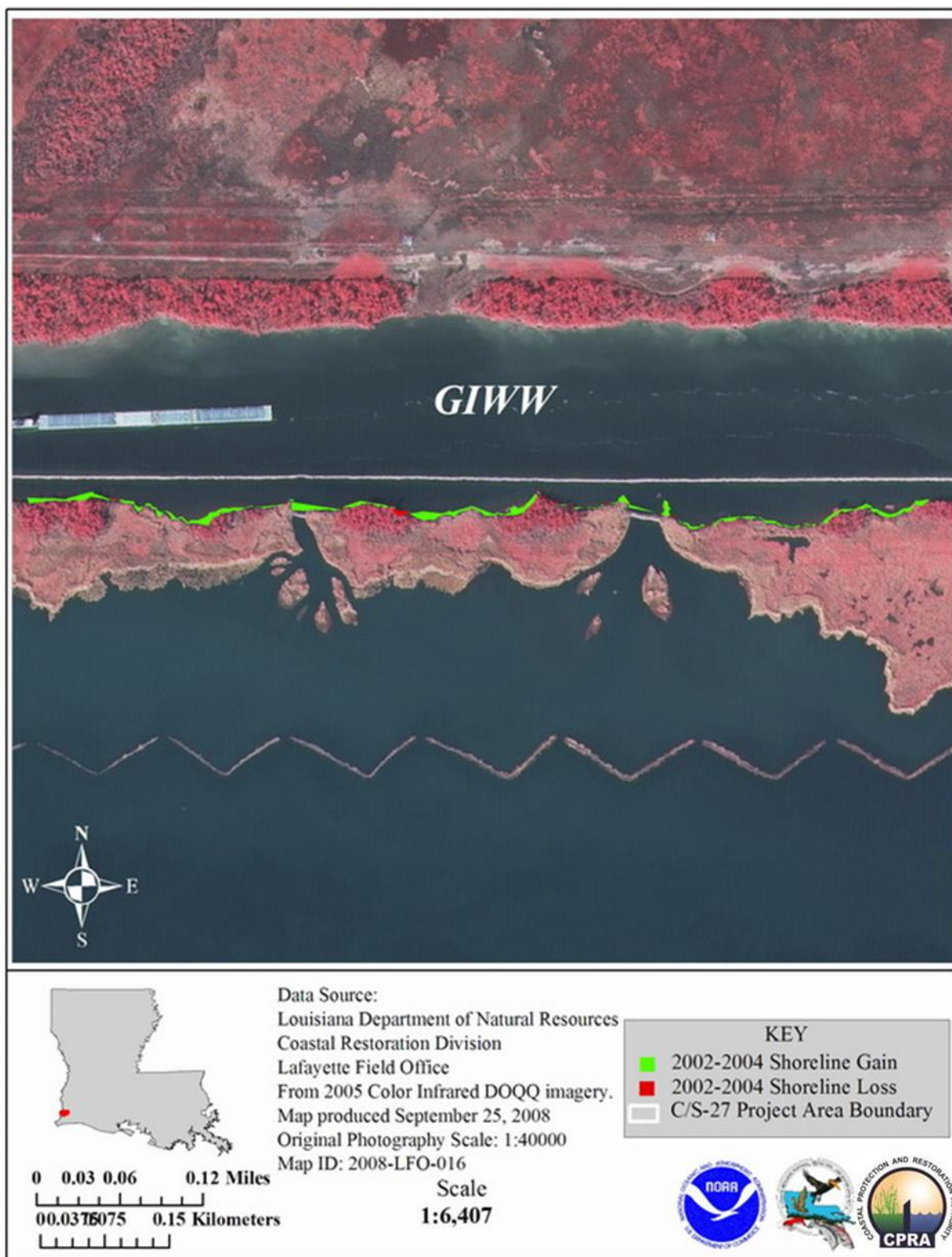
A foreshore rock dike was completed in November of 2001 along the southern shoreline of the GIWW on the northeastern side of the project area between the Black Bayou Cut-off Canal and Gum Cove Ridge. To evaluate the effectiveness of the dikes effect on decreasing erosion, shoreline surveys (dGPS) of the breached portion of the GIWW shoreline along the northern boundary of the impoundment were conducted before construction in March 2000, soon after the rock dike was constructed in March 2002, and about three years after construction in August 2004. Overall, the dike has been successful as this area gained land more than twice as fast during the post construction period than the preconstruction period (Table 3; Figures 11 a and b). Sediments are trapped and settling in the low energy area behind the dike and forming mud flats which are colonized by vegetation (Figure 12).

**Table 3.** Net land gain and rates along the GIWW shoreline/northern impoundment boundary protected by the foreshore dike

Time Period	Net Land Gain	Land Gain Rate
2000-2002 (mainly preconstruction)	0.125 acres	0.063 acres/yr
2002-2004 (post construction)	0.317 acres	0.131 acres/yr



**Figure 11a.** Shoreline change from surveys conducted in March 2000 and March 2002.



**Figure 11b.** Shoreline change from surveys conducted in March 2002 and August 2004.





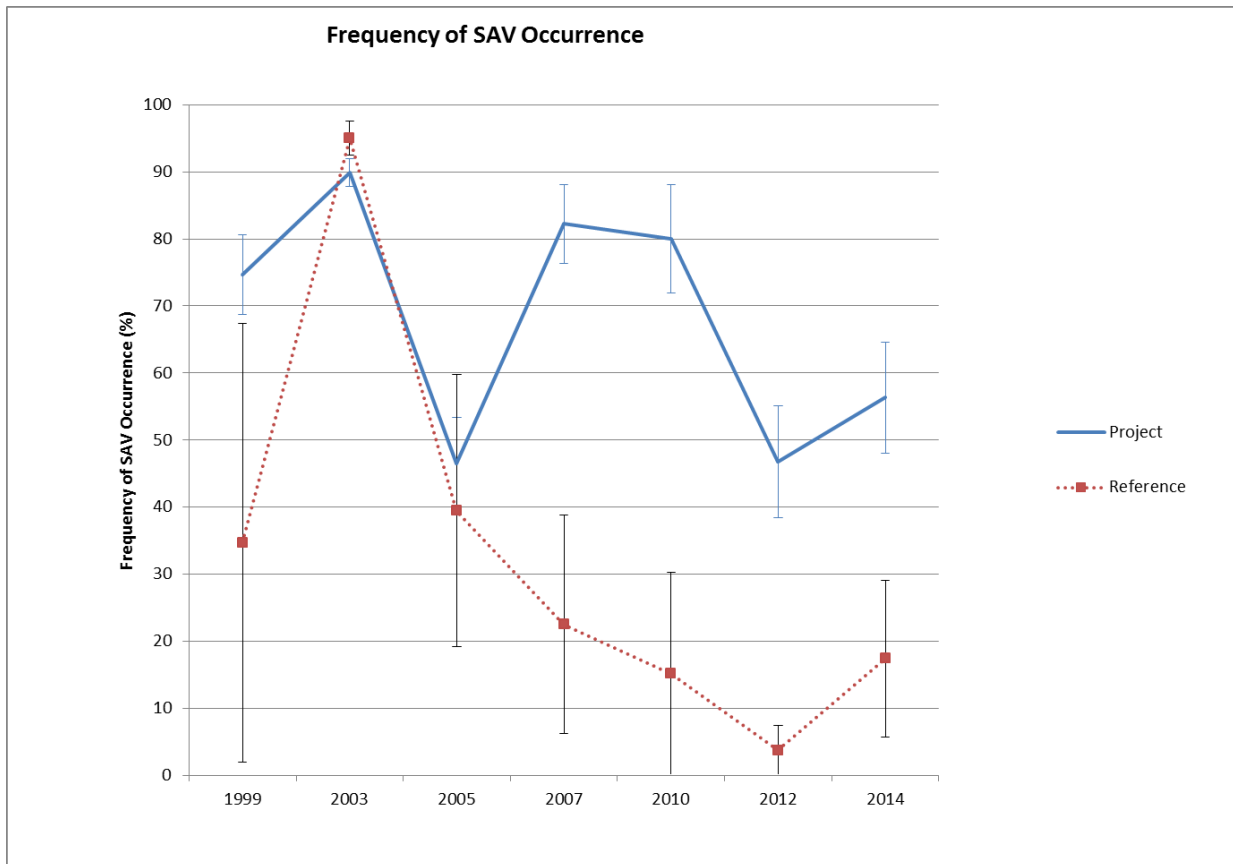
**Figure 12.** Sedimentation and vegetative growth between the GIWW rock dike and dredge material levee along the north side of the impoundment.

### **Submerged Aquatic Vegetation (SAV)**

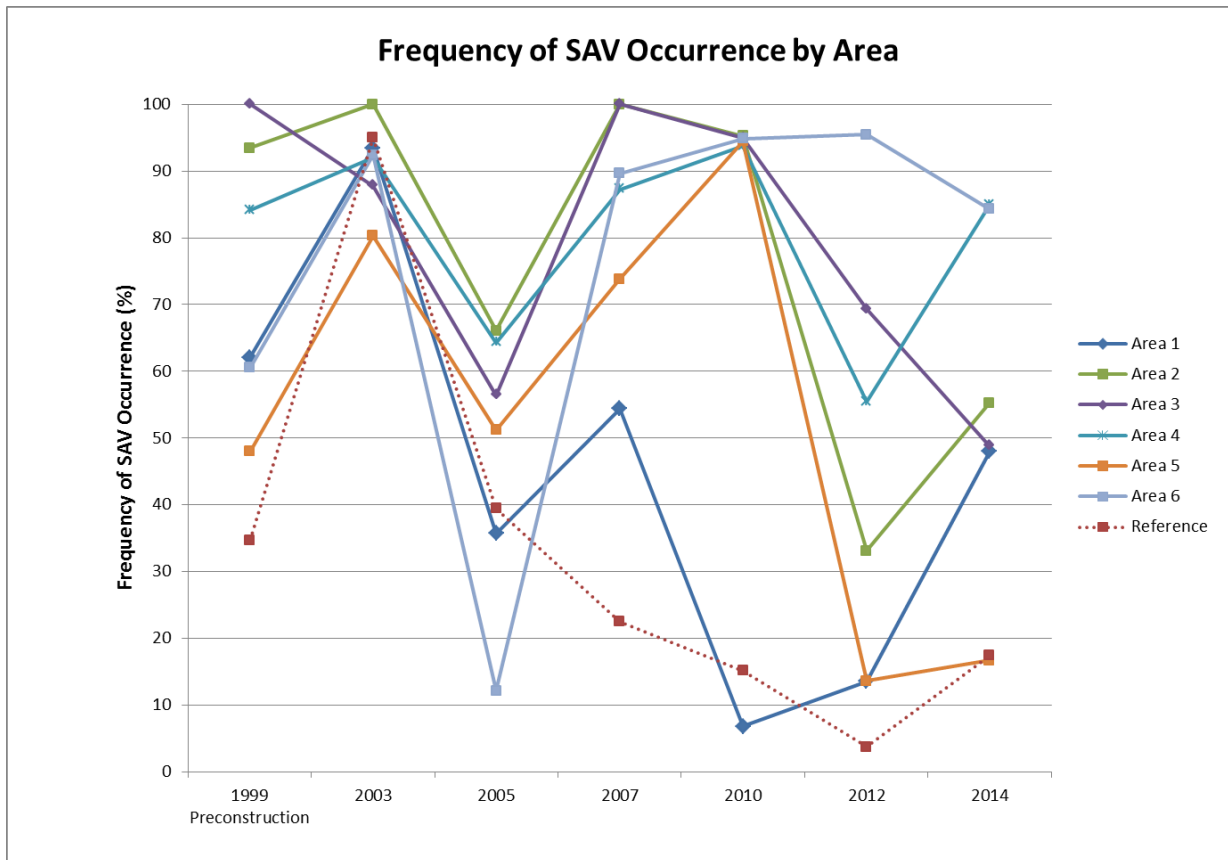
Submerged aquatic vegetation transects were sampled in ponds throughout the project and reference areas from 1999 through 2014 (Figure 3). Overall, SAV coverage has remained high (>50% occurrence) in the project area ( $F_{6,28} = 26.74$ ;  $p = 0.0001$ ), with a sharp reduction in occurrence in 2005 following Hurricane Rita and 2012 following the prolonged drought in 2011 (Figure 13). This trend is not evident in the reference area as the crash in SAV after Hurricane Rita has not recovered to pre hurricane levels even after nearly a decade. Instead of a rebound as seen in the project area the SAV percent occurrence in the reference area continued to fall through 2012 to less than 5% post 2011 drought. Both the project and the reference area have seen a modest increase in SAV from 2012 to 2014 as they were generally wetter fresher years.

In 2010, frequency of occurrence of SAV was more than 90% in all of the areas west of the Black Bayou Cutoff Canal (Areas 2-6) and less than 15% in the reference area and in the impoundment, Area 1. After Hurricane Rita, SAV was present in all areas although frequency of occurrence was only 12% in Area 6 which may have been due to the close proximity of this area to the Sabine Lake/River, a conduit for high salinity water during the storm. Collectively, frequency of occurrence of SAV in the project areas has been high except for immediately after Hurricane Rita and the drought in 2011, while it has greatly declined in the reference area and project impoundment over the course of the study period. This observation is the main cause of a significant interaction between area and year ( $F_{6,72} = 2.75$ ;  $p = 0.0001$ ) (Figure 14) where Area 1 and the reference area decline more than expected in 2010.

SAV has been diverse in the project areas throughout the project life and assemblages have shifted, beginning relatively fresh from 1999 to 2003, saltier in 2005 and 2012, and intermediate in 2007 and 2010 as salinity reduction took place. In 2003, a decrease in *Ruppia maritima* (widgeongrass), an indicator of more saline conditions occurred and *Nymphaea odorata* (American white waterlily) and *Potamogeton pusillus* (small pondweed) (fresher species) were prevalent (Figure 15). Salinity data also showed a freshening of the project area from 2000 - 2003. *Chara spp.* occurrence began in 2003 following project construction in all areas, but did not remain in the reference area after 2003. Species composition shifted in 2005 as *Ruppia maritima* increased, except in the reference area, concurrent with an increase in salinity levels due to the surge of Hurricane Rita. In 2007 and 2010, species composition again shifted with the absence of *Ruppia maritima* and the presence of *Potamogeton pusillus* and *Ceratophyllum demersum* (coon's tail). *Myriophyllum spicatum* (Eurasian watermilfoil) was also absent in the reference area during this time. Salinity levels during 2007 and 2010 appeared to have returned to pre-hurricane levels prior to the drought of 2011 which again heavily disturbed the project impoundment and the reference area SAV assemblages. Following the drought of 2011 *Ruppia maritima* was dominant in Area 1 and the Reference area but almost absent in the rest of the project area. This could indicate that these areas are experiencing higher salinities than the rest of the project area. In 2014 *Ruppia maritima* was very abundant on most sampling transects indicating that the salinity spike of 2011 thought absent in the surface water by spring of 2012 is still impacting the SAV community three growing seasons post drought occurrence.

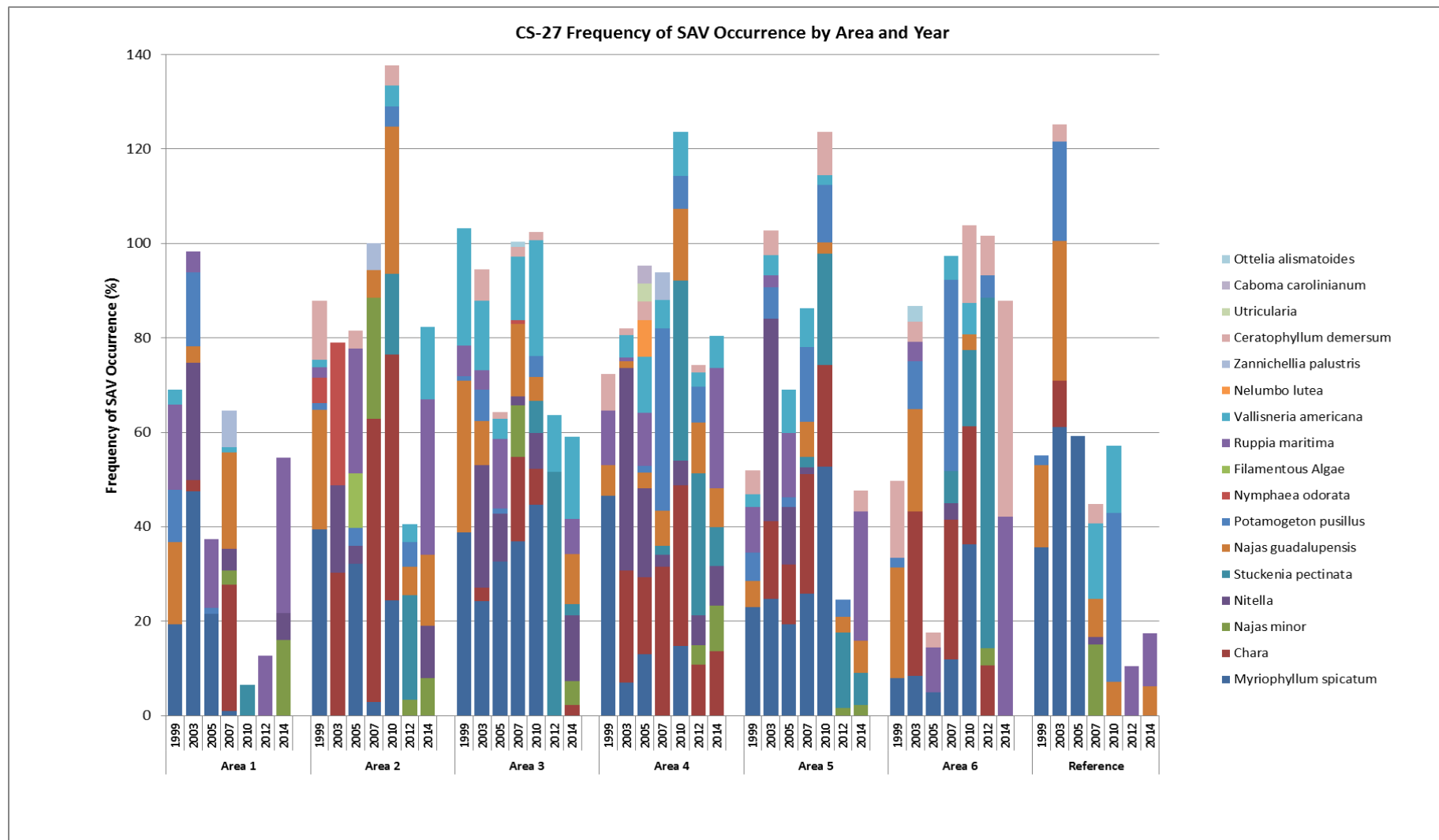


**Figure 13.** Mean and standard errors for SAV frequency of occurrence in the project and reference areas from preproject in 1999 to present.



**Figure 14.** Total percent occurrence of SAV sampled by area and year in late summer. Values are means of three transects (n=3) per area for each year except for area 2 in 2003 (n=1), 2005 (n=2), and 2007 (n=1).



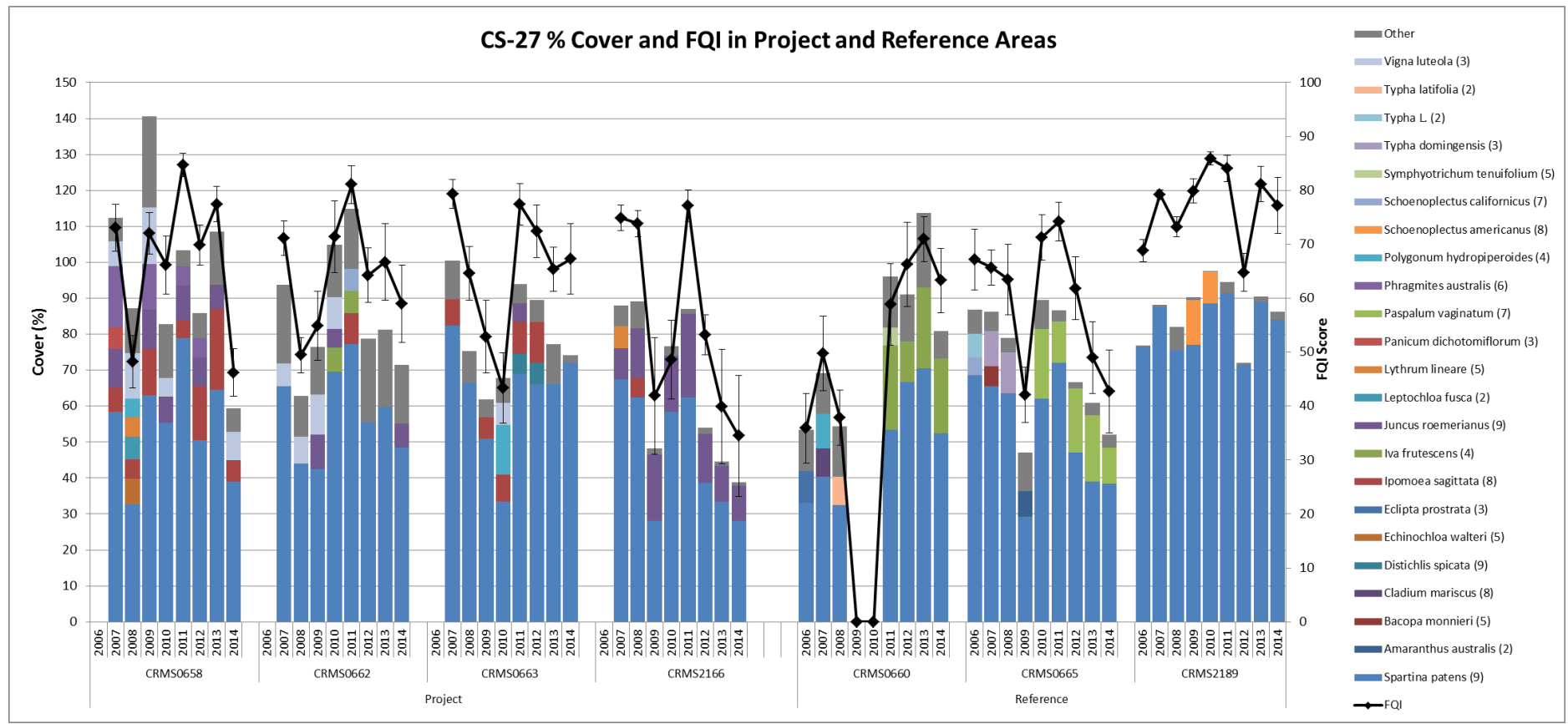


**Figure 15.** Percent occurrence of SAV species by sample area collected in 1999, 2003, 2005, 2007, 2010, 2012, and 2014. Values are the mean of transect values (n=3) per area for each year except for area 2 in 2003 (n=1), 2005 (n=2), and 2007 (n=1).

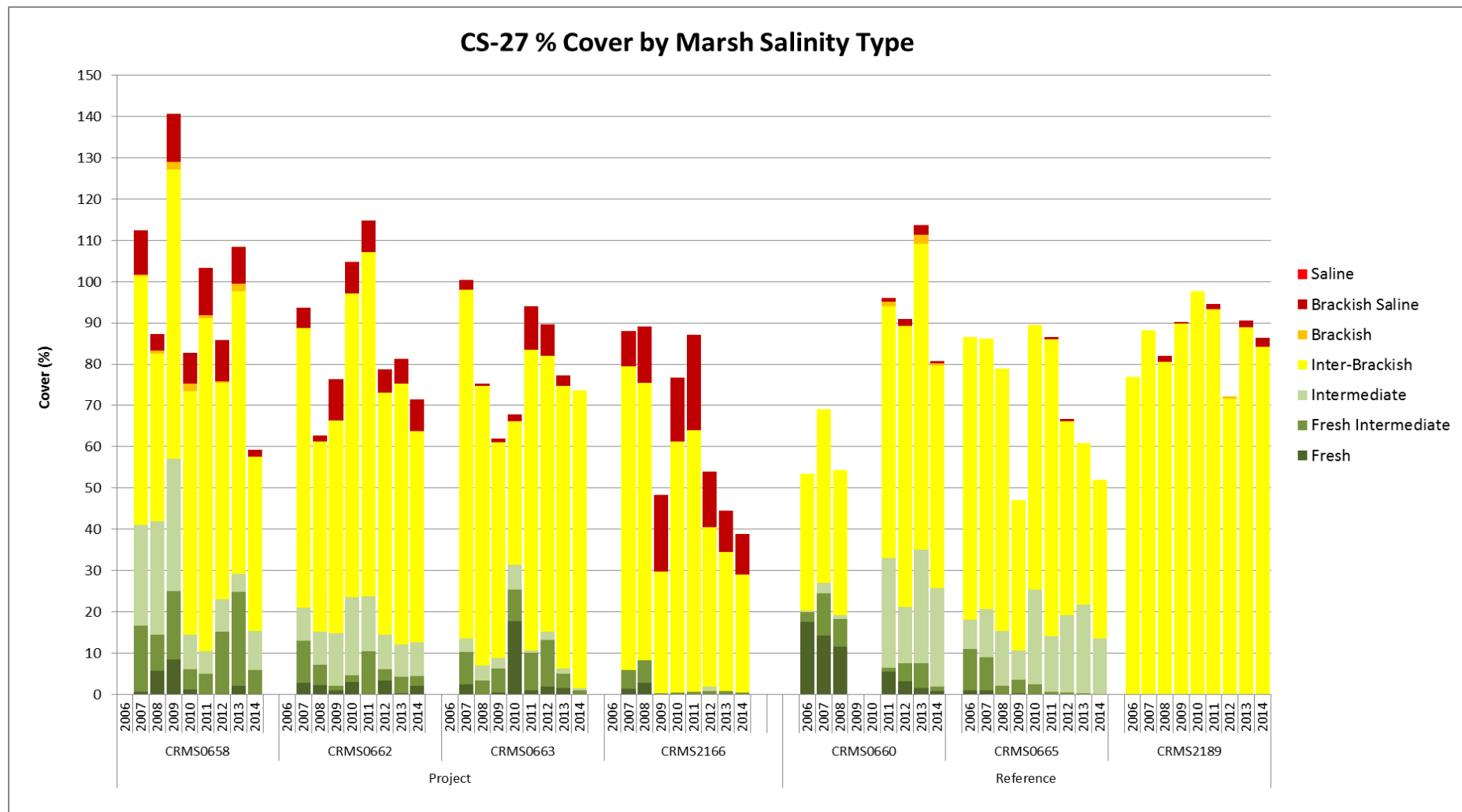
## **Vegetation**

The CS-27 project and reference areas are heavily dominated by *Spartina patens* (saltmeadow cordgrass) and to a lesser extent *Juncus roemerianus* (black needlerush) and *Ipomoea sagittata* (saltmarsh morning-glory) which are all native perennial species common to this marsh type (Figure 16). As such any conditions that are not favorable to the continued growth of *Spartina patens* will adversely affect large areas of both the project and reference areas. The CRMS vegetation surveys in the project and reference area began after the area had already recovered from Hurricane Rita but the effects of Hurricane Ike are fully evident in the 2009 and 2010 percent cover and FQI scores. This effect is especially evident at the reference site CRMS0660 as it was completely denuded of vegetation and never recovered thus was eventually moved to a new location in 2011. Another reference site CRMS0665 also was significantly affected dropping below 50% cover and FQI score during the subsequent season. The project area sites CRMS0663 and CRMS2166 were also damaged by Hurricane Ike but to a lesser extent. A slight to moderate decline in percent cover and FQI score in the project and reference area started in 2012 and has persisted through 2014, as the coverage of *Spartina patens* was reduced without being replaced by another species. This could be attributed to higher water levels in the years following 2011 as high local and upland rains freshened the system (Southern Regional Climate Center). But it is more likely due to the overall stress and damage to the plant communities due to the extreme salinities of 2011. As the droughts full effect on percent cover and FQI reduction were not realized until subsequent growing seasons.

An investigation into the project and reference areas marsh salinity type shows the project area having a slightly more saline cohort of species than the reference area. The marsh salinity type displays the aggregation of all species containing a similar salinity regime for emergent marsh species in the given location (Figure 17). The overall trend in marsh salinity type is that the project area is supporting less of the fresh through intermediate marsh types while maintaining a small but stable brackish saline species contingent annually. This may still be a remnant of hurricane and drought disturbance that is still being expressed in the marsh salinity type and vegetation as a whole. Project sites CRMS0658 and CRMS0663 show a reduction in the amount of brackish vegetation present in 2014 but show a decrease in the other marsh types as well highlighting the overall vegetation reduction in 2014 not a habitat transition. The reference area sites, excluding CRMS 2189 which is unchanged, show a similar loss of the fresher vegetation cohorts. Reference area CRMS0665 behaves very similar to the patterns of the project area leading to the conclusion that the overall loss of fresher habitat and general vegetation reduction is indicative of this area and of the Calcasieu Sabine basin as a whole and is not due to project features.



**Figure 16.** The percent coverage and FQI scores in the project and reference area vegetation data collected from 2006-2014. Reference site CRMS0660 shows a complete loss of vegetation post Hurricane Ike and was reestablished in 2011 in a vegetated location after failing to recover for two years.

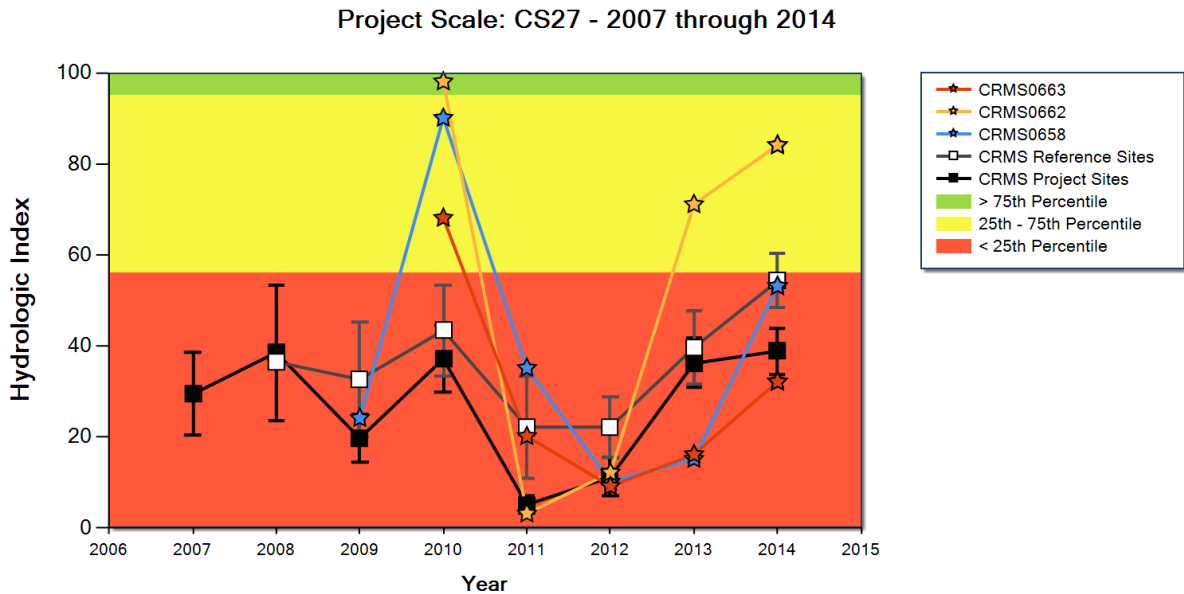


**Figure 17.** The percent coverage of emergent vegetation by marsh salinity type in the project and reference area vegetation data collected from 2006-2014. Reference site CRMS0660 shows a complete loss of vegetation post Hurricane Ike and was reestablished in 2011 in a vegetated location after failing to recover for two years.



### **Hydrologic Index**

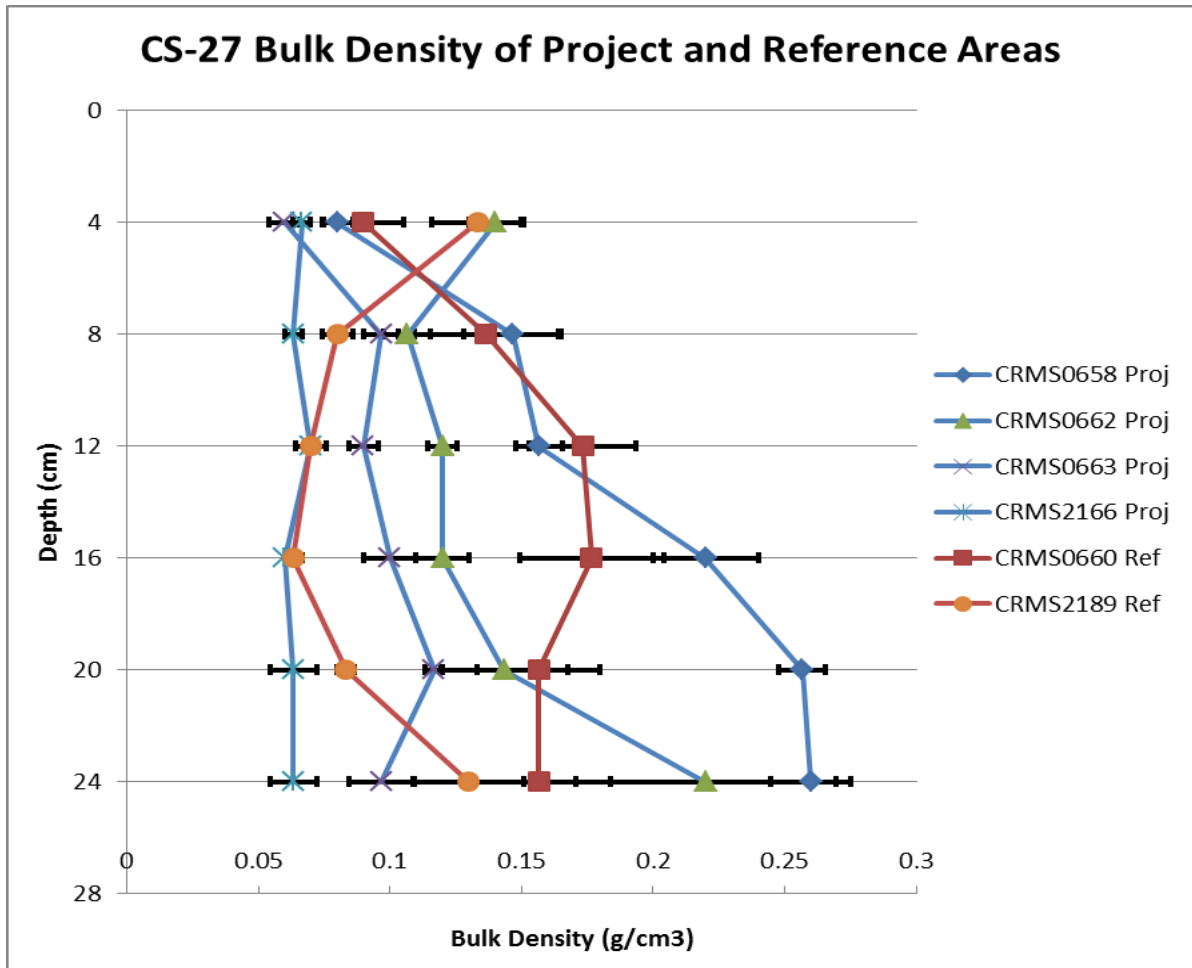
High Hydrologic Index (HI) scores indicate that flooding and salinity conditions are ideal for vegetation growth in a given marsh type. In 2010 the HI scores were higher at CRMS sites within the CS-27 project (CRMS0658, CRMS0662, and CRMS0663) than at CRMS sites outside CS-27 in the same basin and marsh type (Figure 18). In most years the HI scores in the project area were similar to other sites in the region, except CRMS0662 which was much higher in 2013 and 2014 than all other comparable locations. At all sites, low scores in 2011 and 2012 were due to very high average annual salinity for the given marsh type and higher salinity combined with moderate flooding respectively. This pattern of HI is not well supported in the emergent vegetation data that generally shows a peak or stability in 2011 cover and FQI. Most of the project and reference CRMS sites show a continual decline beginning in 2012 and persisting through 2014 except CRMD2189 which displays the inverse likely due to its higher elevation. The HI and emergent marsh temporal pattern shift is likely due to a vegetation time lag as the HI responds immediately to physical stimuli while the emergent marsh vegetation takes multiple growing seasons to process and respond to large events such as hurricanes and extreme droughts. However the SAV sampled as part of the project specific data temporally matched the surface water HI much more favorable as the 2010 HI peak corresponds well with high frequency of occurrence of SAV in the project area and not in the reference area. Also the low HI in 2012 was also linked with low SAV occurrence in both areas with the 2014 rebound in SAV also tracking well with the HI. This close temporal relationship between the HI and SAV occurrence and not emergent marsh may simple be due to the physical proximity of SAV and the water column and the lack of buffering potential such as soil pore water that could cause a time lag in emergent marsh vegetation.



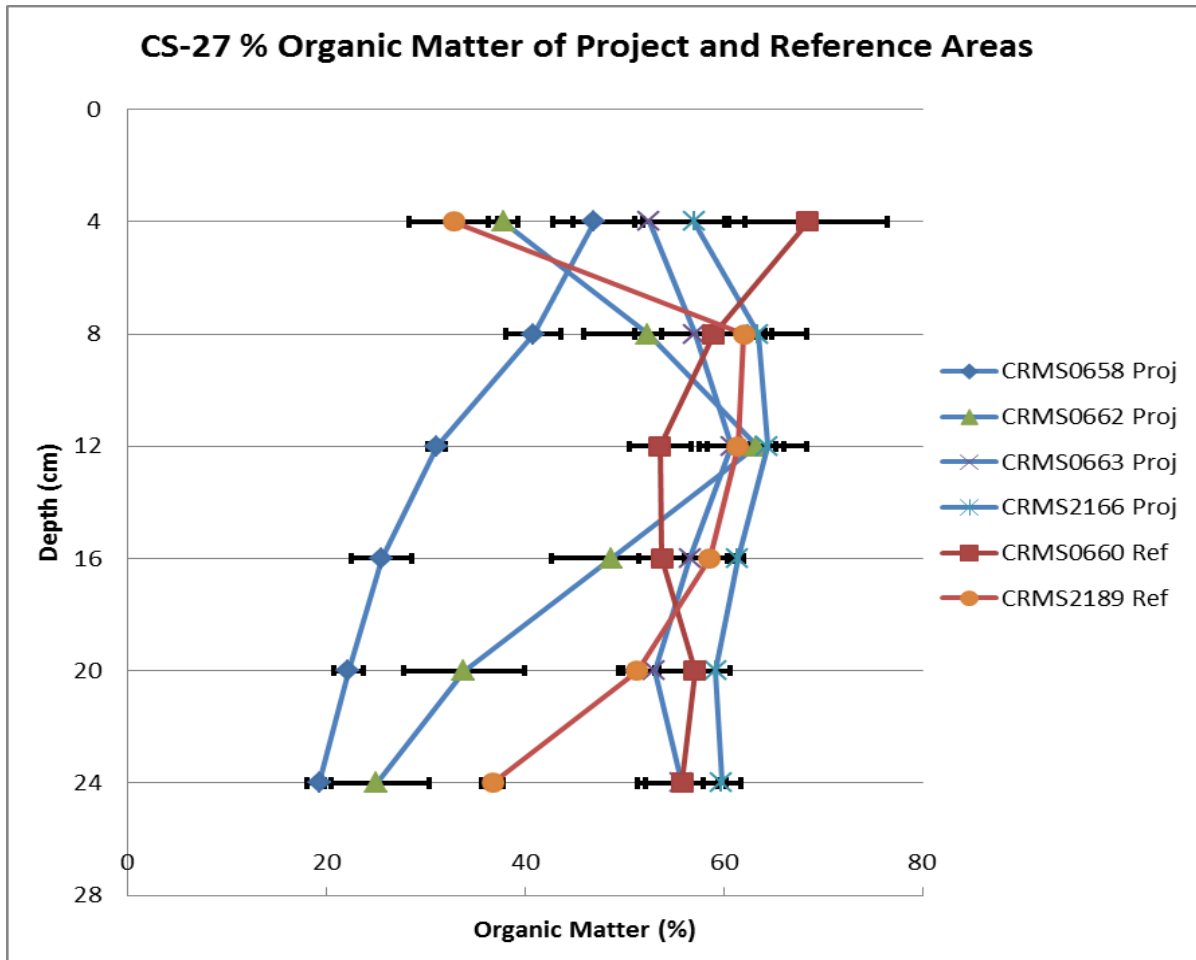
**Figure 18.** Hydrologic Index scores for CRMS sites in the CS-27 project areas shown over time relative to all other CRMS sites (CWPPRA project and reference) within similar marsh types within the Calcasieu/Sabine Basin. CS-27 project area site CRMS2166 was excluded from the HI analysis because it is a marsh well site and not comparable to the other sites surface water locations.

### Soils

Physical soil properties were analyzed from 24 cm (~ 10") deep soil cores collected from four CRMS sites inside the project area and two outside the project area. The soil from the top four to eight cm of all the cores was typical for an intermediate to brackish marsh with low to moderate bulk density ( $0.05 - 0.15 \text{ g/cm}^3$ ) (Figure 20). Soil from many sites were noted upon collection has having many roots throughout the core. Soil core samples began to diverge at 12 cm and below, with CRMS0658 and CRMS0660 being more dense relative to the other sites. There does not appear to be any project effect in the bulk density data just local spatial variation. The bottom half and last sample of the project sites CRMS0658 and CRMS0662 respectively were very dense ( $> 0.2 \text{ g/cm}^3$ ) and had low organic content ( $< 30\%$ ) relative to the other sites (Figure 21), and upon collection the soil was noted to be very silty with few roots. CRMS0658 is positioned along the GIWW and may be perched on dredged material but it does not differ from CRMS0662 in bulk density or percent organic matter at the lowest segments of the core. This indicates a very mineral and stable subsurface platform though the northern portion of the project area. Whereas the rest of the project and reference CRMS sites were fairly uniform from the top to the bottom depth of 24 cm suggesting these sites have a thicker peat like subsurface and the clay platform lays deeper in these areas.



**Figure 20.** Soil bulk density collected at CRMS sites in the project and reference areas. Values are means and standard errors (n=3).

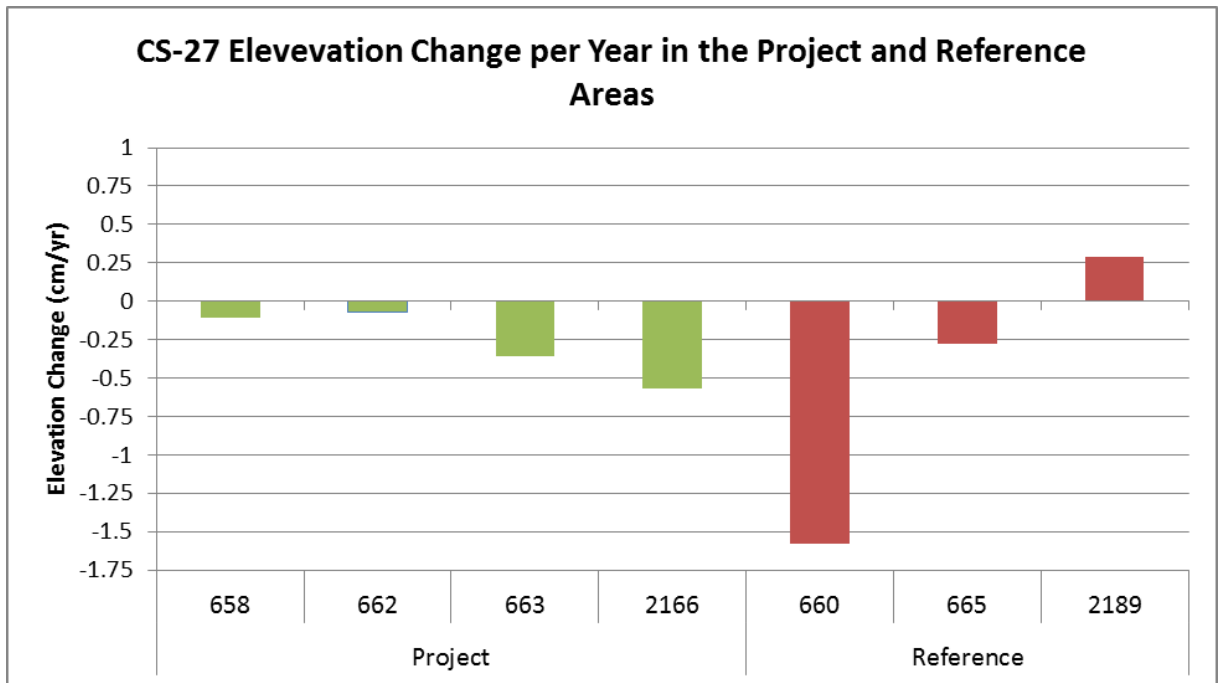


**Figure 21.** Soil percent organic matter collected at CRMS sites in the project and reference areas. Values are means and standard errors (n=3).

### Elevation Change

Subsidence and accretion data collected at the CS-27 project CRMS sites 0658, 0662, 0663, and 2166 along with the reference CRMS sites 0660, 0665, and 2189 generally show the project area had a slight to moderate rates of elevation loss (-0.11 to -0.57 cm/yr) while the reference area was highly variable (+0.29 to -1.58 cm/yr) (Figure 22). Project CRMS0663 and CRMS2166 are likely experiencing slight to moderate increases in inundation when compared to Sabine Pass NOAA tide gauge sea level rise estimate of 0.6 centimeters per year (Zervas 2009). The relative stability and consistency of the project area sites is likely a result from the project features that reduce the tidal export of sediments and organic materials from the project area. The reference area is more variable with CRMS2189 gaining elevation due to its proximity to Sabine Lake and the occasional deposition of storm driven sediments. Reference site CRMS0660 however is losing elevation at an alarming rate of -1.58 cm/yr. This area is highly fragmented, sinking, and appears on the trajectory for continued land loss.





**Figure 22.** Elevation change per year experienced in the project CRMS sites and reference CRMS sites.

## V. Conclusions

### a. Project Effectiveness

Overall the project has met the goal of reducing salt water intrusion into the project area during most environmental conditions as indicated by reduced salinities in the project area relative to the reference area excepted during the extreme drought of 2011. However here were four breaches in the GIWW spoil bank that were repaired in August 2011 which allowed the impoundment to exchange salt water with the reference area. This caused the project impoundment not to be successful at increasing freshwater retention in the project area as it was not a separate hydrologic unit.

The goal to establish emergent wetland vegetation in the shallow open water areas has been partially attained. Most of the bullwhip (*Schoenoplectus californicus*) planted in 2002 and 2003 survived as some plantings were healthy whereas other plantings deteriorated. Establishment of emergent wetland vegetation in the project area was slower than in the reference area from 2000 to 2004. However, from 2000 to 2010, the project land area has remained very stable through multiple negative episodic events (0.0% change), while the reference area has lost land area (-4.0%), presumably due to Hurricanes Rita and Ike. Emergent vegetation in the project area was impacted by Hurricane Ike but recovered by 2010-11. From 2012 through 2014, the cover and quality of vegetation has generally decreased in both the project and reference area, as a result of the high salinities experienced during the 2011 drought.

The foreshore rock dike has effectively reduced shoreline erosion along the GIWW. The widening of the mudflats and shoreline along the northern boundary of the impoundment should provide protection to the emergent wetland vegetation within this portion of the project. Currently there are several small breaches in the foreshore rock dike allowing for hydrologic exchange and the tidal export of mineral and organic matter from the project impoundment.

The frequency of occurrence of SAV in the project areas has been high except immediately after Hurricane Rita in 2005 and during the 2011 drought, while it has significantly declined in the reference area and in the project impoundment over the same temporal scale. Fluctuations over time can be attributed to climatologic forcing functions on the region, such as drought (1999 and 2011) and Hurricanes Rita and Ike (2005, 2008), but these effects appear to be somewhat mitigated by the project features as the majority of the project is less influenced by these large scale regional events compared to the reference area and the impoundment.

Some of the constructed components of the project are in need of preventative maintenance. Erosion at previously noted weir locations has continued under the water's surface creating large scour areas on either side of the rock weirs. The depressions on either side of the weirs threaten the future stability of these project features and maintenance costs and plans are currently being generated. Repairs made during the last maintenance event are in good condition. The breaches which occurred around two of the four plugs behind the GIWW rock dike have been addressed by landowners at no cost to the project. Observations made during

this year's annual inspection such as rusting on the SRT Gate railing and noted sections of displaced rock on the GIWW rock dike do not require maintenance at this time and will continue to be monitored.

#### **b. Recommended Improvements**

The project impoundment is not a separate successfully controlled hydrological unit from the rest of the project area. Whether this is due to water flow over the SRT gate, through the various rock plugs or from a previously unidentified source, synoptic salinity surveys under varying water levels may help in determining the imperfections in the impoundment and identify potential corrective measures.

The hydrodynamic model developed for project design should be duplicated to assess the model validity now that the project and CRMS datasets are so abundant.

For SAV analyses, larger, open-water areas should be avoided. Occurrence of SAV is typically lower in larger water bodies because of greater wave energy and turbidity and may not represent the full project reference disparity.

The installation of staff gauges in convenient locations within the project area is still recommended to assist with monitoring efforts and to tie in local water level observations to project specific and CRMS hydrologic data.

#### **c. Lessons Learned**

Impoundments are designed to hold more water than surrounding areas and are difficult to maintain because of additional hydrodynamic forces on the boundary levees and structures. As such, breaches are difficult to stop and repair within a reasonable timeframe as to not cause disruptions to the project area. A more robust containment levee would be necessary to prevent such breaches in the future. The culverts installed in the southeast corner of the impoundment in addition to the SRT gate proved helpful in relieving high water levels after Hurricane Rita and Ike.

Warning signs in areas of severe current caused by installation of rock or sheet pile weirs should always be included. These signs should be installed in concrete blocks out of the way of traffic since this has proven to be very effective.

Concrete sacks work extremely well in areas where small sections of rock dike need repair and should be considered in these situations.

Guard rails or fences around water control structures should be considered.

It has been learned that alligators will cross at the narrowest point, regardless of elevation. This may be useful in levee repair due to failure initiated by wear from alligator crossing.

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## **APPENDIX A**

### **(Inspection Photographs)**





**Photo 1**—Navigational Aids and signage at Block's Creek



**Photo 2**—Burton Canal Structure w/ missing SW arrow sign



**Photo 3—Black Bayou Cut Off Canal structure**



**Photo 4—SRT Gate**





**Photo 5**—pillow block on SRT Gate flap & railing rust



**Photo 6**—SRT Gate





**Photo 7**—Rock plug near SRT Gate



**Photo 8**—Typical section of rock dike



**Photo 9**—gap in dike with new vegetation between dike & shoreline



**Photo 10**—gap in dike





**Photo 11**—break near closure behind dike



**Photo 12**—gap in dike and break near closure behind dike





**Photo 13**—inlet side of eastern culvert



**Photo 14**—flapgate side of eastern culvert





**Photo 15**—inlet side of western culvert



**Photo 16**—flapgate side of western culvert

**APPENDIX B**  
**(Three Year Budget Projection)**



**BLACK BAYOU HYDROLOGIC RESTORATION/ CS27 / PPL 6**  
**Three-Year Operations & Maintenance Budgets 07/01/2015 - 06/30/2018**

<u>Project Manager</u> <i>Pat Landry</i>	<u>O &amp; M Manager</u> <i>Stan Aucoin</i>	<u>Federal Sponsor</u> <i>NMFS</i>	<u>Prepared By</u> <i>Stan Aucoin</i>
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	<b>2015/2016 (-13)</b>	<b>2016/2017 (-14)</b>	<b>2017/2018 (-15)</b>
<i>Maintenance Inspection</i>	\$ 6,851.00	\$ 7,057.00	\$ 7,269.00
<i>Navigational Aid Inspection</i>	\$ 5,000.00	\$ 5,000.00	\$ 5,000.00
<i>State Administration</i>		\$ -	\$ -
<i>Federal Administration</i>		\$ -	\$ -

**Maintenance/Rehabilitation**

15/16 Description: Install staff gauge

<i>E&amp;D</i>	
<i>Construction</i>	\$ 7,500.00
<i>Construction Oversight</i>	
<i>Sub Total - Maint. And Rehab.</i>	\$ 7,500.00

16/17 Description

<i>E&amp;D</i>	\$ -
<i>Construction</i>	\$ -
<i>Construction Oversight</i>	\$ -
<i>Sub Total - Maint. And Rehab.</i>	\$ -

17/18 Description:

<i>E&amp;D</i>	\$ -
<i>Construction</i>	\$ -
<i>Construction Oversight</i>	\$ -
<i>Sub Total - Maint. And Rehab.</i>	\$ -

	<b>2015/2016 (-13)</b>	<b>2016/2017 (-14)</b>	<b>2017/2018 (-15)</b>
<b><u>Total O&amp;M Budgets</u></b>	<b>\$ 19,351.00</b>	<b>\$ 12,057.00</b>	<b>\$ 12,269.00</b>

<b><u>O &amp; M Budget (3 yr Total)</u></b>	<b>\$ 43,677.00</b>
<b><u>Unexpended O &amp; M Budget</u></b>	<b>\$ 252,341.00</b>
<b><u>Remaining O &amp; M Budget (Projected)</u></b>	<b>\$ 208,664.00</b>



# **OPERATION AND MAINTENANCE BUDGET WORKSHEET**

BLACK BAYOU HYDROLOGIC RESTORATION PROJECT / PROJECT NO. CS-27 / PPL NO. 6 / 2015/2016

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	\$6,851.00	\$6,851.00
General Structure Maintenance	LUMP	0	\$0.00	\$0.00
Engineering and Design	LUMP	0	\$0.00	\$0.00
Operations Contract/ Navigational Aid Inspec.	LUMP	1	\$5,000.00	\$5,000.00
Construction Oversight	LUMP	0	\$0.00	\$0.00

## **ADMINISTRATION**

LDNR / CRD Admin.	LUMP	0	\$0.00	\$0.00
FEDERAL SPONSOR Admin.	LUMP	0	\$0.00	\$0.00
SURVEY Admin.	LUMP	0	\$0.00	\$0.00
OTHER				\$0.00

**TOTAL ADMINISTRATION COSTS: \$0.00**

## **MAINTENANCE / CONSTRUCTION**

### **SURVEY**

SURVEY DESCRIPTION:	Add staff gage.				
	Secondary Monument	EACH	0	\$0.00	\$0.00
	Staff Gauge / Recorders	EACH	1	\$7,500.00	\$7,500.00
	Marsh Elevation / Topography	LUMP	0	\$0.00	\$0.00
	TBM Installation	EACH	0	\$0.00	\$0.00
	OTHER				\$0.00
	TOTAL SURVEY COSTS:				\$7,500.00

### **GEOTECHNICAL**

GEOTECH DESCRIPTION:					
	Borings	EACH	0	\$0.00	\$0.00
	OTHER				\$0.00
	TOTAL GEOTECHNICAL COSTS:				\$0.00

### **CONSTRUCTION**

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	Rock Rip rap	0	0.0	0	\$0.00	\$0.00
	Aggregate Surface Course	0	0.0	0	\$0.00	\$0.00
		0	0.0	0	\$0.00	\$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	\$0.00	\$0.00
	Navigation Aid		EACH	0	\$0.00	\$0.00
	Signage		EACH	0	\$0.00	\$0.00
	General Excavation / Fill		CU YD	0	\$0.00	\$0.00
	Dredging		CU YD	0	\$0.00	\$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	\$0.00	\$0.00
	Timber Piles (each or lump sum)			0	\$0.00	\$0.00
	Timber Members (each or lump sum)			0	\$0.00	\$0.00
	Hardware		LUMP	0	\$0.00	\$0.00
	Materials		LUMP	0	\$0.00	\$0.00
	Mob / Demob		LUMP	0	\$0.00	\$0.00
	Contingency		LUMP	0	\$0.00	\$0.00
	General Structure Maintenance		LUMP	0	\$0.00	\$0.00
	OTHER				\$0.00	\$0.00
	OTHER				\$0.00	\$0.00
	OTHER				\$0.00	\$0.00
TOTAL CONSTRUCTION COSTS:					\$0.00	

**TOTAL OPERATIONS AND MAINTENANCE BUDGET: \$19,351.00**

# **OPERATION AND MAINTENANCE BUDGET WORKSHEET**

BLACK BAYOU HYDROLOGIC RESTORATION PROJECT / PROJECT NO. CS-27 / PPL NO. 6 / 2016-2017

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	\$7,057.00	\$7,057.00
General Structure Maintenance	LUMP	0	\$0.00	\$0.00
Engineering and Design	LUMP	0	\$0.00	\$0.00
Operations Contract/ Navigational Aid Inspec.	LUMP	1	\$5,000.00	\$5,000.00
Construction Oversight	LUMP	0	\$0.00	\$0.00

## **ADMINISTRATION**

LDNR / CRD Admin.	LUMP	0	\$0.00	\$0.00
FEDERAL SPONSOR Admin.	LUMP	0	\$0.00	\$0.00
SURVEY Admin.	LUMP	0	\$0.00	\$0.00
OTHER				\$0.00

**TOTAL ADMINISTRATION COSTS: \$0.00**

## **MAINTENANCE / CONSTRUCTION**

### **SURVEY**

SURVEY DESCRIPTION:					
	Secondary Monument	EACH	0	\$0.00	\$0.00
	Staff Gauge / Recorders	EACH	0	\$0.00	\$0.00
	Marsh Elevation / Topography	LUMP	0	\$0.00	\$0.00
	TBM Installation	EACH	0	\$0.00	\$0.00
	OTHER				\$0.00
	TOTAL SURVEY COSTS:				\$0.00

### **GEOTECHNICAL**

GEOTECH DESCRIPTION:					
	Borings	EACH	0	\$0.00	\$0.00
	OTHER				\$0.00
	TOTAL GEOTECHNICAL COSTS:				\$0.00

### **CONSTRUCTION**

CONSTRUCTION DESCRIPTION:					
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE
	Rock Rip rap	0	0.0	0	\$0.00
	Aggregate Surface Course	0	0.0	0	\$0.00
		0	0.0	0	\$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	\$0.00
	Navigation Aid		EACH	0	\$0.00
	Signage		EACH	0	\$0.00
	General Excavation / Fill		CU YD	0	\$0.00
	Dredging		CU YD	0	\$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	\$0.00
	Timber Piles (each or lump sum)			0	\$0.00
	Timber Members (each or lump sum)			0	\$0.00
	Hardware		LUMP	0	\$0.00
	Materials		LUMP	0	\$0.00
	Mob / Demob		LUMP	0	\$0.00
	Contingency		LUMP	0	\$0.00
	General Structure Maintenance		LUMP	0	\$0.00
	OTHER				\$0.00
	OTHER				\$0.00
OTHER				\$0.00	
TOTAL CONSTRUCTION COSTS:					\$0.00

**TOTAL OPERATIONS AND MAINTENANCE BUDGET: \$12,057.00**

# **OPERATION AND MAINTENANCE BUDGET WORKSHEET**

BLACK BAYOU HYDROLOGIC RESTORATION PROJECT / PROJECT NO. CS-27 / PPL NO. 6 / 2017-2018

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	\$7,269.00	\$7,269.00
General Structure Maintenance	LUMP	0	\$0.00	\$0.00
Engineering and Design	LUMP	0	\$0.00	\$0.00
Operations Contract/ Navigational Aid Inspec.	LUMP	1	\$5,000.00	\$5,000.00
Construction Oversight	LUMP	0	\$0.00	\$0.00

## **ADMINISTRATION**

LDNR / CRD Admin.	LUMP	0	\$0.00	\$0.00
FEDERAL SPONSOR Admin.	LUMP	0	\$0.00	\$0.00
SURVEY Admin.	LUMP	0	\$0.00	\$0.00
OTHER				\$0.00

**TOTAL ADMINISTRATION COSTS: \$0.00**

## **MAINTENANCE / CONSTRUCTION**

### **SURVEY**

SURVEY DESCRIPTION:				
Secondary Monument	EACH	0	\$0.00	\$0.00
Staff Gauge / Recorders	EACH	0	\$0.00	\$0.00
Marsh Elevation / Topography	LUMP	0	\$0.00	\$0.00
TBM Installation	EACH	0	\$0.00	\$0.00
OTHER				\$0.00
<b>TOTAL SURVEY COSTS:</b>				<b>\$0.00</b>

### **GEOTECHNICAL**

GEOTECH DESCRIPTION:				
Borings	EACH	0	\$0.00	\$0.00
OTHER				\$0.00
<b>TOTAL GEOTECHNICAL COSTS:</b>				<b>\$0.00</b>

### **CONSTRUCTION**

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
Rock Rip rap	0	0.0	0	\$0.00	\$0.00
Aggregate Surface Course	0	0.0	0	\$0.00	\$0.00
	0	0.0	0	\$0.00	\$0.00
Filter Cloth / Geogrid Fabric	SQ YD	0		\$0.00	\$0.00
Navigation Aid	EACH	0		\$0.00	\$0.00
Signage	EACH	0		\$0.00	\$0.00
General Excavation / Fill	CU YD	0		\$0.00	\$0.00
Dredging	CU YD	0		\$0.00	\$0.00
Sheet Piles (Lin Ft or Sq Yds)		0		\$0.00	\$0.00
Timber Piles (each or lump sum)		0		\$0.00	\$0.00
Timber Members (each or lump sum)		0		\$0.00	\$0.00
Hardware	LUMP	0		\$0.00	\$0.00
Materials	LUMP	0		\$0.00	\$0.00
Mob / Demob	LUMP	0		\$0.00	\$0.00
Contingency	LUMP	0		\$0.00	\$0.00
General Structure Maintenance	LUMP	0		\$0.00	\$0.00
OTHER				\$0.00	\$0.00
OTHER				\$0.00	\$0.00
OTHER				\$0.00	\$0.00
<b>TOTAL CONSTRUCTION COSTS:</b>					<b>\$0.00</b>

**TOTAL OPERATIONS AND MAINTENANCE BUDGET: \$12,269.00**

## **APPENDIX C**

### **(Field Inspection Notes)**



### MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: CS-27 Black Bayou Hydrologic Restoration  
 Structure No. \_\_\_\_\_ N/A \_\_\_\_\_

Structure Description: Blocks's Creek Weir w/ Boat Bay  
 Burton Canal Weir w/ Boat Bay  
 Black Bayou Cut-Off Canal w/ Barge Bay  
 Culvert1/Culvert2

Date of Inspection: April 9, 2015 Time: 12:30pm  
 June 26, 2015  
 Inspector(s): Stan Aucoin and Dion Broussard (CPRA)  
 John Foret (NMFS)  
 Water Level Inside: \_\_\_\_\_ Outside: \_\_\_\_\_  
 Salinity: \_\_\_\_\_  
 Weather Conditions: cloudy and warm

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Block's Creek Weir	Good			1	Scouring taking place on each side of the structure. 20 ft deep on Black Bayou side and 14ft deep on interior. Sill is at 4.5ft. Two arrow signs are missing. No other maintenance required at this time.
Burton Canal Weir	Good			2	Scouring taking place on each side of the of the wier. 29.5ft on Sabine river side and 33.7ft deep on interior. Sill is at 6.5ft
Black Bayou Cut-Off Canal Weir	Good			3	Scouring is taking place on each side of the weir. 33.5ft deep on the GIWW side and 23ft deep on interior. Sill is at 10.5ft deep.
Culvert1/Culvert2	good			13-16	Good condition
Timber Piles	N/A				
Timber Wales	N/A				
Galv. Pile Caps	N/A				
Navigational Aid Lights	Good				Inspected quarterly.
Signage /Supports	Good				See note on Block's creek
Rip Rap	Good				

What are the conditions of the existing levees?  
 Are there any noticeable breaches?  
 Settlement of rock plugs and rock weirs?  
 Position of stoplogs at the time of the inspection?  
 Are there any signs of vandalism?



### MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: CS-27 Black Bayou Hydrologic Restoration

Date of Inspection: April 9, 2015 Time: 12:30 am

Structure No. \_\_\_\_ N/A

Inspector(s): Stan Aucoin and Dion Broussard (CPRA)

John Foret (NMFS)

Structure Description: SRT Gate and Rock Plug

Water Level Inside: \_\_\_\_\_ Outside: \_\_\_\_\_

Salinity: \_\_\_\_\_

Type of Inspection: Annual

Weather Conditions: clear skies and cool temperatures

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	Good			6	Rusting at sheet pile seams. Will continue to monitor.
Steel Grating	N/A				
Stop Logs	N/A				
Hardware	Good				
Timber Piles	Good				
Timber Wales	Good				
Galv. Pile Caps	Good				
SRT Gate	Good		Moderate	4-6	Pillow blocks were replaced during last inspection. Gate is in good condition. The railing above the gate is showing signs of corrosion. No maintenance required at this time.
Signage / Supports Vinton Canal	Good			4	Good condition.
Rip Rap (fill)	Good				
Rock Plug (Concrete sack repair)	Good			7	Good condition

What are the conditions of the existing levees?

Are there any noticeable breaches?

Settlement of rock plugs and rock weirs?

Position of stoplogs at the time of the inspection?

Are there any signs of vandalism?

### MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: CS-27 Black Bayou Hydrologic Restoration

Date of Inspection: April 9, 2015 Time: 12:30pm

Structure No. \_\_\_\_ N/A

Inspector(s): Stan Aucoin, Dion Broussard (CPRA)

John Foret (NMFS)

Structure Description: GIWW Rock Dike

Water Level Inside: \_\_\_\_\_ Outside: \_\_\_\_\_

Salinity: \_\_\_\_\_

Type of Inspection: Annual

Weather Conditions: cloudy skies and warm

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	N/A				
Stop Logs	N/A				
Hardware	N/A				
Timber Piles	N/A				
Timber Wales	N/A				
Galv. Pile Caps	N/A				
Earthen Plugs	Fair				The spoil behind the rock dike at the natural Black Bayou has washed away on the western end. This will continue to be monitored.
Signage / Supports	Poor				Warning signs at the Vinton and Black Bayou closures are missing.
Rip Rap (fill) GIWW Rock Dike	Good			9-12	There is a gap in the rock dike at the natural Black Bayou in front of the gap in the earthen plug. The rock is approximately 2-3 ft below the water surface. The first and second gaps from the east have solid marsh behind them. The third has a connection through the marsh on the west side approx. six feet wide with significant flow. Several small gaps in the dike were noticed; however, rock is still present at the base providing shoreline protection. There are low areas along the rest of the dike but they are still functioning as intended. Tie-ins on both ends of the rock dike are stable. Sediment accretion behind the dike is evident and vegetation is expanding.

What are the conditions of the existing levees?

Are there any noticeable breaches?

Settlement of rock plugs and rock weirs?

Position of stoplogs at the time of the inspection?

Are there any signs of vandalism?